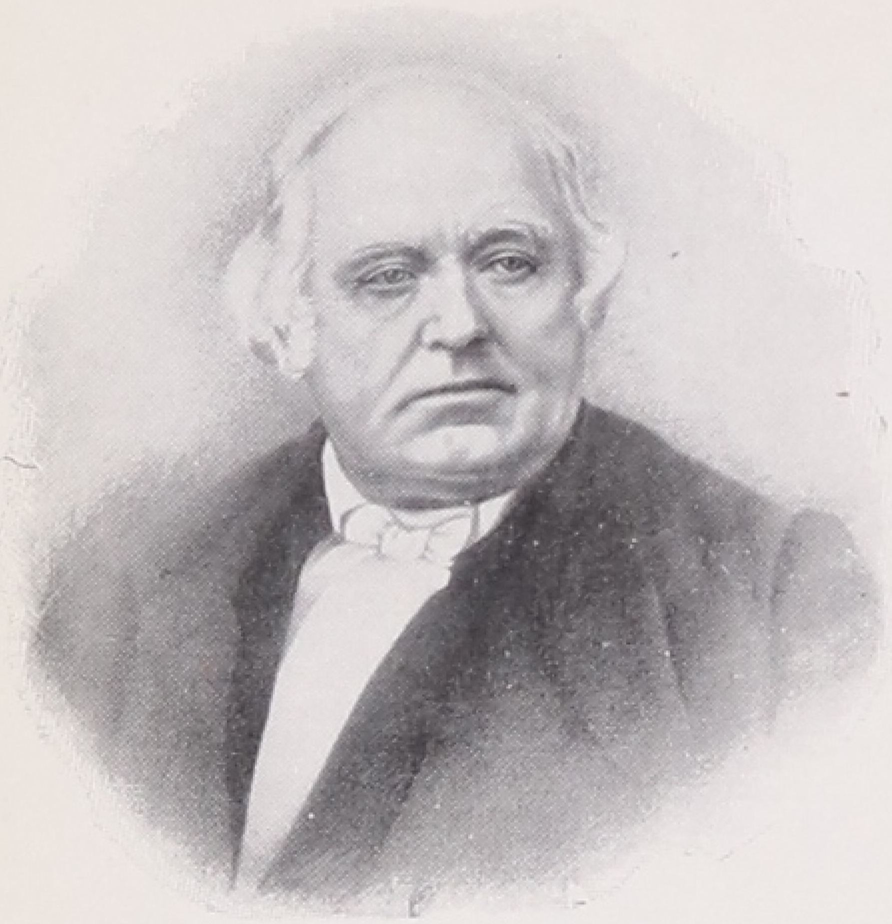
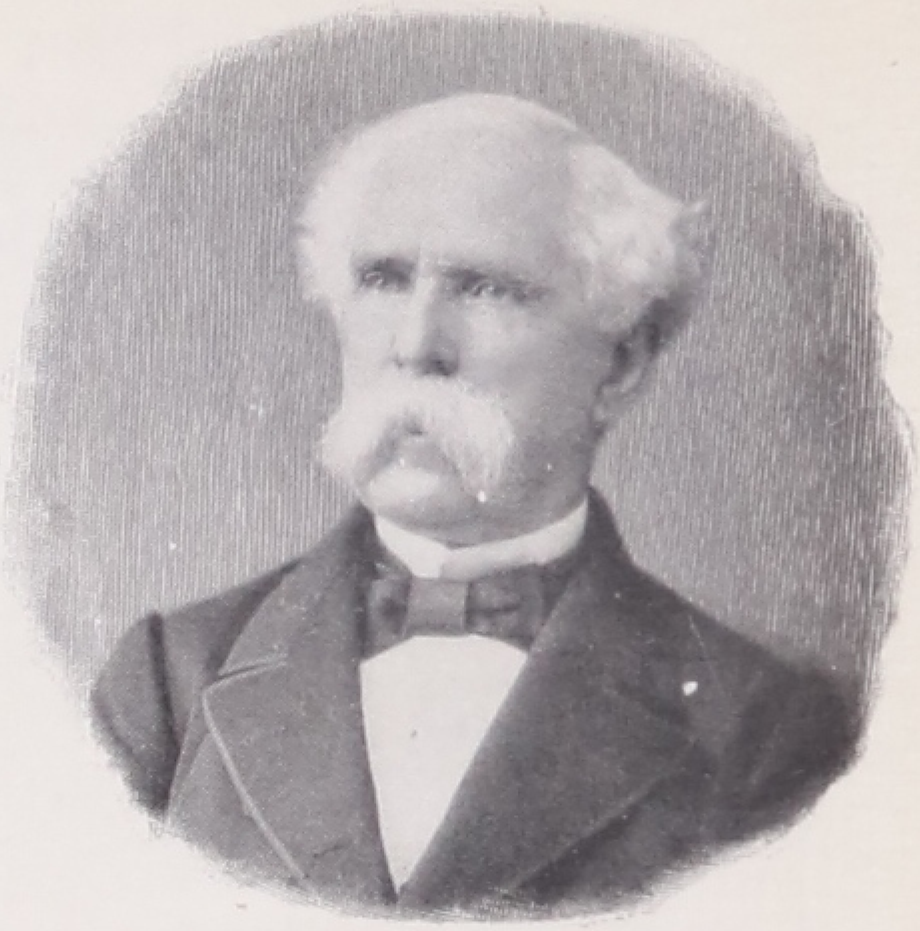


ISAAC NEWTON.
(Commissioner of Agriculture, 1862-1867.)



HORACE CAPRON.
(Commissioner of Agriculture, 1867-1871.)

JEREMIAH M. RUSK.
(Secretary of Agriculture, 1889-1893.)

FREDERICK WATTS.
(Commissioner of Agriculture, 1871-1877.)

GEORGE B. LORING.
(Commissioner of Agriculture, 1881-1885.)

HEADS (DECEASED) OF THE DEPARTMENT OF AGRICULTURE.

YEARBOOK

OF THE

UNITED STATES

DEPARTMENT OF AGRICULTURE.

1899.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1900.

[CHAPTER 23, Stat. at L., 1895.]

AN ACT providing for the public printing and binding and distribution of public documents.

* * * * * * *

Section 73, paragraph 2:

The Annual Report of the Secretary of Agriculture shall hereafter be submitted and printed in two parts, as follows: Part One, which shall contain purely business and executive matter which it is necessary for the Secretary to submit to the President and Congress; Part Two, which shall contain such reports from the different Bureaus and Divisions, and such papers prepared by their special agents, accompanied by suitable illustrations, as shall, in the opinion of the Secretary, be specially suited to interest and instruct the farmers of the country, and to include a general report of the operations of the Department for their information. There shall be printed of Part One, one thousand copies for the Senate, two thousand copies for the House, and three thousand copies for the Department of Agriculture; and of Part Two, one hundred and ten thousand copies for the use of the Senate, three hundred and sixty thousand copies for the use of the House of Representatives, and thirty thousand copies for the use of the Department of Agriculture, the illustrations for the same to be executed under the supervision of the Public Printer, in accordance with directions of the Joint Committee on Printing, said illustrations to be subject to the approval of the Secretary of Agriculture: and the title of each of the said parts shall be such as to show that such part is complete in itself.

PREFACE.

In the Annual Report of the Secretary of Agriculture for 1898 there occurred the following reference to the Yearbook for 1899:

* * * For 1899 I am considering the propriety of making a special effort to prepare a publication which shall contain a résumé of the achievements in the United States in every branch of science as related to agriculture during the nineteenth century, for distribution at the Paris Exposition.

The plan thus suggested was not lost sight of, and in the circular letter instructing the chiefs of Bureaus, Divisions, and Offices as to the matter to be supplied the Secretary expressed his earnest desire that the idea presented in his Annual Report for 1898, quoted above, should be carried out as far as possible in the preparation of the papers for the present volume. He said:

I desire that the Yearbook for 1899, the distribution of which will occur during the last year of this century, shall present to the reader a picture of the development of agriculture in the United States during the nineteenth century and of its condition at the present time, and show in a special manner the effect upon agricultural industry of the application of science in its several branches to the service of agriculture. Every Bureau and Division in the Department charged with scientific work should therefore contribute one or two articles reviewing the progress made in the application to agriculture of the particular science with which it is concerned.

In the execution of this design it has been necessary to somewhat limit the number of papers, owing to the space desired for the proper treatment of the various subjects. In addition to the Annual Report of the Secretary, which, in accordance with the law providing for the publication of the Yearbook, has the first place in the volume, there are but twenty-six papers. A glance at the list of titles on page 5 will show that in the main the plan laid down by the Secretary has been carried out. A wide latitude, however, has been allowed to each writer in the presentation of his subject, as each one was dealing with what has been practically his life work. The result is, it is believed, to present for the first time within the covers of a single volume a fairly comprehensive review of the progress and development of a century in almost every branch of scientific inquiry having a direct practical bearing upon agriculture.

It is gratifying to record in this connection that Congress has made provision for an extra distribution of this number of the Yearbook by providing a special edition to be available for foreign distribution during the time of the Paris Exposition of 1900—an edition which will be literally "extra," not only as to number but as to workmanship. So much for the miscellaneous papers from the several chiefs of the Bureaus, Divisions, and Offices. Two papers only are contributed by others than Department officers and employees, that on the "Work of the breeder in improving live stock" and that on the "Development of transportation in the United States." These papers were prepared by two gentlemen each of whom is especially qualified by the experience of a lifetime to treat of the subject assigned to him.

The general character of the Appendix has not been materially changed; such modifications as have been made are in the direction of expansion, with a view to the making of this part of the Yearbook a convenient and full ready-reference book, excluding no information which might be of value to any resident in a rural district. The steps which have already been taken in this direction will be continued in the future.

It should be said in speaking of the Appendix, the character of which precludes the giving of individual credit for the various contributions, that all the Bureaus, Divisions, and Offices of the Department have supplied a share, oftentimes involving a very large amount of work, not infrequently more than is required in the preparation of papers for the main body of the volume. The illustrations include sixty-three plates and numerous text figures.

It is proper to state here that acknowledgments are due to many persons for information kindly supplied by them to the writers of several of the papers comprised in this volume, but the frequency of such aid makes it impossible to particularize, and confines us to this general acknowledgment on behalf of the writers thus favored.

GEO. WM. HILL,
Editor.

WASHINGTON, D. C., *April 20, 1900.*

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TEXT FIGURES.

YEARBOOK

OF THE

U. S. DEPARTMENT OF AGRICULTURE.

REPORT OF THE SECRETARY.

To the President:

I have the honor to report upon the work of the Department of Agriculture for the year ending June 30, 1899. This report touches upon the work regularly carried on by the several Bureaus, Divisions, and Offices, and also indicates the new lines of scientific inquiry inaugurated by the Department for the benefit of producers in the several States. A brief summary precedes more extended consideration. I have also endeavored to give in sufficient detail the reasons for the estimates presented to Congress to carry on the work for the coming year.

SUMMARY.

Weather Bureau.—The extension of the Weather Bureau service around the Caribbean Sea has been abundantly successful in noting the first indications of cyclones, forecasting their movements, and giving timely warning to our Navy, to merchant vessels, and to producers and others interested on land.

Division of Chemistry.—This Division is becoming a necessity to every Department of the Government in the making of chemical analyses. Foods are investigated, preservatives of all kinds examined, sugar beets analyzed, etc. An interesting inquiry has been made into the change which takes place in the composition of grains grown repeatedly on the same soil.

Division of Entomology.—Since Dr. Howard has shown owners of Smyrna fig trees on the Pacific coast how to get the fruit fertilized, there is good reason to believe that in a few years we shall obtain our fine figs from that locality. Investigation by this Division shows that house flies and mosquitoes may be greatly reduced by removing the propagating conditions.

Division of Botany.—The Department is gathering information regarding the life history of the plants that supply commerce with india rubber and gutta-percha, and should Congress be pleased to give direction, it will seek the plant zones in our island possessions where these commodities may be produced. The United States now pays $30,000,000 annually for rubber. We import between $4,000,000 and $5,000,000 worth of Egyptian cotton annually. Experimentation indicates strongly that, on suitable soils properly cultivated, this article can be grown here.

Biological Survey.—Plants and animals thrive and produce best where they are most at home. The Biological Survey is endeavoring to find the most congenial conditions for our plants and animals.

Division of Vegetable Physiology and Pathology.—The hybridizing of grains is being conducted by the Division of Vegetable Physiology and Pathology, with a view to securing varieties (rust-resisting, drought-resisting, and cold-resisting) better suited to our varied soils and climates. Hybridization will also be applied in the immediate future to cotton, and efforts are now being made to get a hardier orange tree by the same process. The diseases of plants in the several States, including a serious fungous disease affecting sea-island cotton, and the diseases of fruit trees are also being studied.

Division of Pomology.—This Division continues to experiment in many localities throughout the country with fruit-bearing trees, plants, and vines. For example, 119 varieties of the finer table grapes of Europe have been grafted on Phylloxera-resistant American stocks and sent to North Carolina and Florida. Special work is being done on the Pacific coast to get more definite data regarding the adaptability of varieties to that locality.

Division of Forestry.—The Division of Forestry is introducing practical and paying forestry on a large scale among lumbermen, and extensive experimentation in tree planting is being conducted, with cooperation on the part of those interested in woodcraft in the several States.

Division of Soils.—The irrigation farmer of the West is being helped by the mapping and extended investigation of alkali soils and by the reclamation of injured or abandoned land, many acres of which have become sterile through the injudicious use of water.

Division of Agrostology.—Cropping reduces the organic material in the soil. Long-continued cropping renders the soil unproductive. Grasses and legumes are the best agencies for restoring this organic matter. The Division of Agrostology is experimenting with home and foreign grasses and legumes in all sections of our country, to build up worn-out soils in some cases and to introduce useful varieties in others.

Office of Experiment Stations.—Cooperation between the Department and the experiment stations becomes closer every year. Assistance from the States is increasing and the farmers of the several States are appreciating their station work more and more. Experimentation in Alaska has begun with Congressional aid. This work should be extended to Hawaii, Puerto Rico, and the Philippine Islands, so that they may be enabled to supply the United States with tropical products, our importations of which amount to over two hundred million dollars annually.

Office of Public Road Inquiries.—There is great interest at the present time in the public highways of the country. Extensive experimentation is being conducted by the Department in cooperation with local authorities in building sample roads from the materials found in different localities, and in the laying of steel track.

Division of Publications.—During the year 603 publications were issued and over 7,000,000 copies distributed among the people. Of the Farmers' Bulletins, 2,437,000 copies were printed and distributed, which did not meet the full demand.

SECTION OF FOREIGN MARKETS.—Shows rapid growth of American commerce with all parts of the world. We continue to sell raw material to foreign countries, from which they manufacture high-selling articles. Trade regulations are prohibitory against American meats in some European countries where importations of cheap grains from which meats are made are encouraged. The American farmer can not afford to export nitrogenous grains or mill feeds for this purpose.

BUREAU OF ANIMAL INDUSTRY.—The work of this Bureau increases rapidly. Meat inspection was conducted last year at 138 abattoirs in 41 cities. The ante-mortem inspections were 53,223,176, while the number in 1892 was 3,809,459. The third year of experimentation with hog cholera shows that from 75 to 80 per cent of hogs injected with serum are saved. Encouraging results have come from the introduction of dairy products into foreign markets. The Department sends shipments abroad for the purpose of ascertaining the facts regarding such products; these facts are published, and commerce naturally follows.

DIVISION OF STATISTICS.—Fifty thousand crop reporters keep the Division of Statistics informed regarding the condition of our staple crops, and every effort is being made to promptly give the people the facts as they are found.

GARDENS AND GROUNDS.—The grounds of the Department and its extensive greenhouses serve a useful purpose, more than 100,000 plants and bulbs, all of economic value, having been distributed during the year by the Superintendent. This official is now prepared to supply tea plants for experimentation in the Gulf States.

SEED DISTRIBUTION.—The Department in the distribution of seeds is aiming to conform to the original spirit of the law by the importation and distribution of what is rare and valuable.

WEATHER BUREAU.

The establishment of stations around the Caribbean Sea has enabled the Weather Bureau to note the first approach of the West Indian cyclone and to warn shipmasters in port and interested persons on land, with remarkable certainty, of its approach.

EXTRACTS FROM THE REPORT OF THE CHIEF.

The following paragraphs, extracted from the report of the chief of the Bureau, set forth some important features of the work:

COLD WAVES.

Among the most important warnings issued by the Weather Bureau are those which give notice to agricultural and commercial interests of the approach of periods of abnormally low temperature. Warnings of this class have been particularly successful during the past year, and a not unimportant feature of the advices has been estimates of the probable continuation of injuriously low temperatures. In fact, a special effort has been made, and will be sustained, to afford all interests all the information regarding future weather conditions that is warranted by modern methods, appliances, and skill in forecasting. The recognized accuracy of the temperature forecasts have caused them to be closely watched by

various interests, and in the commercial centers movements of perishable goods are almost absolutely controlled by advices received from the Weather Bureau.

By far the most important cold wave, or series of cold waves, of the winter crossed the country from the North Pacific to the South Atlantic coasts during the first half of February, 1899, damaging crops and fruits in the Southern States to the extent of millions of dollars. During the first eight days of the month the lowest temperatures on record were reported at points in the North Pacific coast States; from the 9th to the 12th many places in the Central, Western, and Northwestern States reported the coldest weather on record. During the 13th and 14th the cold wave overspread the Southern and Eastern States, attended on the 13th by the lowest temperature on record from the Southern Rocky Mountain slope to the South Atlantic coast, by zero temperature to the Gulf coast of Alabama, and by a snowstorm of unprecedented severity in the Middle Atlantic States.

The Weather Bureau forecasts and warnings gave ample and timely notice to all interests of the advance of the cold wave, and special reports and newspaper comments gave unquestionable evidence that the warnings prompted protective measures whereby crops, live stock, and perishable goods and merchandise to the value of hundreds of thousands of dollars were saved. Along the Middle Atlantic and New England coasts the character of the storm called for the display of hurricane signals, the extreme warnings of the Bureau.

The detailed action taken in connection with this cold wave and storm and the numerous newspaper comments relating thereto, for which space can not be given here, will be found in the Monthly Weather Review for February, 1899. All reports and comments bear witness to the fact that the work of the Weather Bureau in connection with this, the severest cold wave in the history of the Southern States, was as nearly perfect as the most approved methods of disseminating warnings would permit. The amount saved by stockmen in the West and Southwest, by truck growers in the Southwest, and by fruit growers, gardeners, and orchardists in the Southern States, and more especially in Florida, is incalculable. The superintendent of the Florida East Coast Line reports that the warnings sent along his line of road, fifteen hours in advance of the cold wave, alone resulted in saving one-half of the vegetable crop, and that the value of the crop was estimated at $1,000,000. The exceptionally severe character of the storm along the Middle Atlantic and New England coasts amply justified the special warnings sent to that section.

CLIMATE AND CROP SERVICE OF CUBA AND PUERTO RICO.

In the latter part of October, 1898, instructions were given to the official at San Juan, Puerto Rico, to establish a climate and crop service in that island, and later similar action was taken in Cuba. Sufficient instruments and shelters of standard pattern were sent into both islands and voluntary stations established as rapidly as the cooperation of efficient observers could be secured. By the opening of the new year the issue of the Weekly Climate and Crop Bulletin had begun in Puerto Rico, and similar bulletins for Cuba were first issued about the middle of May. The illness of the official in charge unfortunately interrupted the work of the Puerto Rico section, which, however, was resumed in May and has since continued. Arrangements have been completed by which monthly section reports, after the standard, for both Puerto Rico and Cuba will be issued hereafter, work on the first report, that for May, 1899, for Puerto Rico, being well in hand. Notwithstanding the serious difficulties which were encountered in the prosecution of the climate and crop work in these islands, due in a great measure to the fact that the Spanish language is exclusively spoken, much has been successfully accomplished, as evidenced by the fact that both sections issued weekly bulletins with regularity after the middle of May.

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From the many courteous and complimentary communications that have been received and notices published in the newspapers, both on the islands and in the United States, it is evident that the efforts to establish this service have been successful and have met a popular need. As the residents of the islands become more conversant with the aims and scope of the service they will appreciate more fully what a great benefit it is, both climatologically and financially.

LOSS OF LIFE AND PROPERTY BY LIGHTNING.

The collection of statistics of loss of life and property by lightning, referred to in a previous report, has been continued. The number of deaths by lightning stroke in the calendar year 1898 was 367 and the number of injuries 494. The places where the proportion of deaths to total population was the greatest were the Upper Missouri Valley and portions of the Rocky Mountain region. The proportion of deaths by lightning in the United States to the total population is about five in a million, which, it may be remarked, is higher than the average of most countries.

Nine hundred and sixty-six barns, sheds, etc., 735 dwellings, stores, and office buildings, 95 churches and schools, and 70 other buildings were struck and damaged by lightning, the approximate loss being about a million and a half dollars. Of the buildings struck, 40 were provided with lightning rods, 855 were not, and in 952 cases it could not be ascertained whether the building was provided with rods or not.

Nine hundred and sixty-four head of cattle, 306 horses, 30 mules, 426 sheep, and 116 hogs were killed by lightning during the calendar year above referred to. The total value of the stock reported killed was $48,257.

Lightning has caused great loss of life and property thus far during the calendar year 1899.

AERIAL OBSERVATIONS.

At the close of the last fiscal year 17 kite stations were in operation and 248 ascensions had been made, in each of which the elevation attained exceeded 1,000 feet. The work was continued until about the middle of November, 1898, at which time 1,217 ascensions of 1,000 feet and over had been made.

The study of the records of temperature, pressure, and humidity thus secured was intrusted to Mr. H. C. Frankenfield, forecast official, whose first report has been submitted. For the first time in the history of meteorology we have facts instead of hypotheses as to the average gradient of temperature up to 6,000 or 8,000 feet, free from all injurious influences, and for so many days and over such a large region of country that it has a broad significance; evidently it is the only proper gradient to be used in reducing atmospheric pressures or temperatures, up or down, from any observer's level. Notwithstanding the imperfections attending the beginnings of any such entirely novel work, these 17 stations, with their 1,217 ascensions in the course of six months, have probably added more to our knowledge of vertical gradients of temperature, humidity, and wind, in the daytime of summer, in the lower portion of the atmosphere, than the sum total of all that was previously known upon the subject.

STUDY OF TEMPERATURES AT STATIONS IN ALASKA.

The Bureau is studying the temperatures at stations in Alaska to learn what effect they may have on rainfall in California, and when cables are laid around the Pacific, with observers stationed at numerous places, the ocean currents and their effect on our Pacific coast, being more intelligently studied, will be better understood. The

severe cold wave of last winter that destroyed so many fruit trees suggests the continued improvement of our means of observation.

RECOMMENDATIONS.

The greatest returns from the large sum ($1,022,482) spent annually in the maintenance of the Weather Bureau are from the warnings to marine interests of destructive storms and predictions of cold waves and frosts for the benefit of agriculture and commerce. An appropriation of $95,000 for the purpose of equipping storm-warning stations with improved lights and durable iron flagstaffs and towers from which these important signals can be advantageously displayed is urgently recommended; also an increase of $25,000 in the fund for telegraphing weather reports and improving the river and flood service in order to meet the numerous demands now almost daily made upon the Weather Bureau of this Department by boards of trade, cotton exchanges, marine associations, and large individual owners of ocean, lake, and river property.

DIVISION OF CHEMISTRY.

This Division has continued its study of various soils under identical conditions with satisfactory results. Improved methods of analysis have been devised and published for the benefit of agricultural chemists throughout the country.

Much time and attention has been given to the investigation of food products to ascertain the composition and nutritive value of commercial foods, and definite data have been secured.

Careful and systematic research has been made in this Division for preservatives of all kinds which may have been used on meats. The attitude which the Department should take toward preservatives has been frequently outlined in official reports, but it may be as well to restate it here, as the matter is of great importance. It is well stated in the report of the Chemist, as follows:

> It is not regarded as a wise thing to absolutely prohibit the use of preservatives in foods. Since, however, all chemicals which have the properties of preserving foods also have a tendency to interfere with the processes of digestion, it is held to be imperative that no food should be offered for sale which contains a preservative without having this fact plainly stated upon the label of the package. Not only should the label state that the food product contains a preservative, but it should also give the name of the preservative and the quantity employed. In this way the intending purchaser is fully informed in regard to the character of the product which he buys. While it has been established that a healthy stomach can, from time to time, receive with impunity food containing small quantities of preservatives, it is by no means certain that the continued practice of ingesting preservatives in foods would not produce serious injury. On the other hand, it is also quite certain that weak or diseased stomachs may suffer temporary or permanent injury from even minute quantities of preservatives.

Twenty tons of high-grade sugar-beet seed were imported from Europe for distribution under the supervision of the Chemist. This

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was sent out mainly through the experiment stations of the States and Territories interested in beet culture. Analyses of beets have also been made by the Division for all recipients of this seed desiring such service.

The State, War, Treasury, Justice, Post-Office, and Interior Departments of the Government frequently call upon the Department of Agriculture to have chemical work done, which suggests the wisdom of preparing to do this work through statutory provision recognizing the Division of Chemistry and providing means to enable it to serve all the Departments.

Deterioration in the gluten content of wheat is being inquired into.

DIVISION OF ENTOMOLOGY.

There are very large numbers of Smyrna fig trees in California that have never matured fruit because the flowers were never fertilized. Dr. Howard, chief of this Division, suggested the importation of an insect (*Blastophaga grossorum*) which in the Mediterranean countries fertilizes this fig. This has been successfully done, and the insects have multiplied and fertilized many figs that matured. Dr. Swingle, who made the importation, is carefully studying the habits of the insect and teaching the owners of the trees regarding it. There is good reason to hope that our country will get its figs in future from the Pacific coast. The Division continues its study of injurious insects that may invade our territory from contiguous countries. Volunteer observers for this Division are studying injurious Puerto Rican insects. Sets of injurious insects are being received from several foreign countries with which we have intercourse. Insects are being studied that are destructive to forests in the Northwestern States. The life history of the San Jose scale, through the work of this Division and State officials, is now well understood. Experimentation in this Division to learn whether this scale would live on dried fruit has convinced most foreign importers that they may safely handle this product.

Investigation is being made by this Division regarding the ability and likelihood of house flies and mosquitoes to carry disease; also by many scientists, who call upon Dr. Howard for exact information bearing upon the life histories of these insects. Life histories of insects injurious to garden crops, grasses, and tobacco are being made out. The Mexican boll weevil is under consideration and the geographic distribution of insects is being carefully mapped, both lines of work in cooperation with local entomologists. Experimental work with remedies and their effects on foliage has been undertaken. The honey bee is being studied along practical lines, such as the preventing of swarming, queen rearing, and the like. Much inquiry comes regarding the large bee of the East, which we will import as soon as arrangements can be made.

various interests, and in the commercial centers movements of perishable goods are almost absolutely controlled by advices received from the Weather Bureau.

By far the most important cold wave, or series of cold waves, of the winter crossed the country from the North Pacific to the South Atlantic coasts during the first half of February, 1899, damaging crops and fruits in the Southern States to the extent of millions of dollars. During the first eight days of the month the lowest temperatures on record were reported at points in the North Pacific coast States; from the 9th to the 12th many places in the Central, Western, and Northwestern States reported the coldest weather on record. During the 13th and 14th the cold wave overspread the Southern and Eastern States, attended on the 13th by the lowest temperature on record from the Southern Rocky Mountain slope to the South Atlantic coast, by zero temperature to the Gulf coast of Alabama, and by a snowstorm of unprecedented severity in the Middle Atlantic States.

The Weather Bureau forecasts and warnings gave ample and timely notice to all interests of the advance of the cold wave, and special reports and newspaper comments gave unquestionable evidence that the warnings prompted protective measures whereby crops, live stock, and perishable goods and merchandise to the value of hundreds of thousands of dollars were saved. Along the Middle Atlantic and New England coasts the character of the storm called for the display of hurricane signals, the extreme warnings of the Bureau.

The detailed action taken in connection with this cold wave and storm and the numerous newspaper comments relating thereto, for which space can not be given here, will be found in the Monthly Weather Review for February, 1899. All reports and comments bear witness to the fact that the work of the Weather Bureau in connection with this, the severest cold wave in the history of the Southern States, was as nearly perfect as the most approved methods of disseminating warnings would permit. The amount saved by stockmen in the West and Southwest, by truck growers in the Southwest, and by fruit growers, gardeners, and orchardists in the Southern States, and more especially in Florida, is incalculable. The superintendent of the Florida East Coast Line reports that the warnings sent along his line of road, fifteen hours in advance of the cold wave, alone resulted in saving one-half of the vegetable crop, and that the value of the crop was estimated at $1,000,000. The exceptionally severe character of the storm along the Middle Atlantic and New England coasts amply justified the special warnings sent to that section.

CLIMATE AND CROP SERVICE OF CUBA AND PUERTO RICO.

In the latter part of October, 1898, instructions were given to the official at San Juan, Puerto Rico, to establish a climate and crop service in that island, and later similar action was taken in Cuba. Sufficient instruments and shelters of standard pattern were sent into both islands and voluntary stations established as rapidly as the cooperation of efficient observers could be secured. By the opening of the new year the issue of the Weekly Climate and Crop Bulletin had begun in Puerto Rico, and similar bulletins for Cuba were first issued about the middle of May. The illness of the official in charge unfortunately interrupted the work of the Puerto Rico section, which, however, was resumed in May and has since continued. Arrangements have been completed by which monthly section reports, after the standard, for both Puerto Rico and Cuba will be issued hereafter, work on the first report, that for May, 1899, for Puerto Rico, being well in hand. Notwithstanding the serious difficulties which were encountered in the prosecution of the climate and crop work in these islands, due in a great measure to the fact that the Spanish language is exclusively spoken, much has been successfully accomplished, as evidenced by the fact that both sections issued weekly bulletins with regularity after the middle of May.

From the many courteous and complimentary communications that have been received and notices published in the newspapers, both on the islands and in the United States, it is evident that the efforts to establish this service have been successful and have met a popular need. As the residents of the islands become more conversant with the aims and scope of the service they will appreciate more fully what a great benefit it is, both climatologically and financially.

LOSS OF LIFE AND PROPERTY BY LIGHTNING.

The collection of statistics of loss of life and property by lightning, referred to in a previous report, has been continued. The number of deaths by lightning stroke in the calendar year 1898 was 367 and the number of injuries 494. The places where the proportion of deaths to total population was the greatest were the Upper Missouri Valley and portions of the Rocky Mountain region. The proportion of deaths by lightning in the United States to the total population is about five in a million, which, it may be remarked, is higher than the average of most countries.

Nine hundred and sixty-six barns, sheds, etc., 735 dwellings, stores, and office buildings, 95 churches and schools, and 70 other buildings were struck and damaged by lightning, the approximate loss being about a million and a half dollars. Of the buildings struck, 40 were provided with lightning rods, 855 were not, and in 952 cases it could not be ascertained whether the building was provided with rods or not.

Nine hundred and sixty-four head of cattle, 306 horses, 30 mules, 426 sheep, and 116 hogs were killed by lightning during the calendar year above referred to. The total value of the stock reported killed was $48,257.

Lightning has caused great loss of life and property thus far during the calendar year 1899.

AERIAL OBSERVATIONS.

At the close of the last fiscal year 17 kite stations were in operation and 248 ascensions had been made, in each of which the elevation attained exceeded 1,000 feet. The work was continued until about the middle of November, 1898, at which time 1,217 ascensions of 1,000 feet and over had been made.

The study of the records of temperature, pressure, and humidity thus secured was intrusted to Mr. H. C. Frankenfield, forecast official, whose first report has been submitted. For the first time in the history of meteorology we have facts instead of hypotheses as to the average gradient of temperature up to 6,000 or 8,000 feet, free from all injurious influences, and for so many days and over such a large region of country that it has a broad significance; evidently it is the only proper gradient to be used in reducing atmospheric pressures or temperatures, up or down, from any observer's level. Notwithstanding the imperfections attending the beginnings of any such entirely novel work, these 17 stations, with their 1,217 ascensions in the course of six months, have probably added more to our knowledge of vertical gradients of temperature, humidity, and wind, in the daytime of summer, in the lower portion of the atmosphere, than the sum total of all that was previously known upon the subject.

STUDY OF TEMPERATURES AT STATIONS IN ALASKA.

The Bureau is studying the temperatures at stations in Alaska to learn what effect they may have on rainfall in California, and when cables are laid around the Pacific, with observers stationed at numerous places, the ocean currents and their effect on our Pacific coast, being more intelligently studied, will be better understood. The

severe cold wave of last winter that destroyed so many fruit trees suggests the continued improvement of our means of observation.

RECOMMENDATIONS.

The greatest returns from the large sum ($1,022,482) spent annually in the maintenance of the Weather Bureau are from the warnings to marine interests of destructive storms and predictions of cold waves and frosts for the benefit of agriculture and commerce. An appropriation of $95,000 for the purpose of equipping storm-warning stations with improved lights and durable iron flagstaffs and towers from which these important signals can be advantageously displayed is urgently recommended; also an increase of $25,000 in the fund for telegraphing weather reports and improving the river and flood service in order to meet the numerous demands now almost daily made upon the Weather Bureau of this Department by boards of trade, cotton exchanges, marine associations, and large individual owners of ocean, lake, and river property.

DIVISION OF CHEMISTRY.

This Division has continued its study of various soils under identical conditions with satisfactory results. Improved methods of analysis have been devised and published for the benefit of agricultural chemists throughout the country.

Much time and attention has been given to the investigation of food products to ascertain the composition and nutritive value of commercial foods, and definite data have been secured.

Careful and systematic research has been made in this Division for preservatives of all kinds which may have been used on meats. The attitude which the Department should take toward preservatives has been frequently outlined in official reports, but it may be as well to restate it here, as the matter is of great importance. It is well stated in the report of the Chemist, as follows:

> It is not regarded as a wise thing to absolutely prohibit the use of preservatives in foods. Since, however, all chemicals which have the properties of preserving foods also have a tendency to interfere with the processes of digestion, it is held to be imperative that no food should be offered for sale which contains a preservative without having this fact plainly stated upon the label of the package. Not only should the label state that the food product contains a preservative, but it should also give the name of the preservative and the quantity employed. In this way the intending purchaser is fully informed in regard to the character of the product which he buys. While it has been established that a healthy stomach can, from time to time, receive with impunity food containing small quantities of preservatives, it is by no means certain that the continued practice of ingesting preservatives in foods would not produce serious injury. On the other hand, it is also quite certain that weak or diseased stomachs may suffer temporary or permanent injury from even minute quantities of preservatives.

Twenty tons of high-grade sugar-beet seed were imported from Europe for distribution under the supervision of the Chemist. This

was sent out mainly through the experiment stations of the States and Territories interested in beet culture. Analyses of beets have also been made by the Division for all recipients of this seed desiring such service.

The State, War, Treasury, Justice, Post-Office, and Interior Departments of the Government frequently call upon the Department of Agriculture to have chemical work done, which suggests the wisdom of preparing to do this work through statutory provision recognizing the Division of Chemistry and providing means to enable it to serve all the Departments.

Deterioration in the gluten content of wheat is being inquired into.

DIVISION OF ENTOMOLOGY.

There are very large numbers of Smyrna fig trees in California that have never matured fruit because the flowers were never fertilized. Dr. Howard, chief of this Division, suggested the importation of an insect (*Blastophaga grossorum*) which in the Mediterranean countries fertilizes this fig. This has been successfully done, and the insects have multiplied and fertilized many figs that matured. Dr. Swingle, who made the importation, is carefully studying the habits of the insect and teaching the owners of the trees regarding it. There is good reason to hope that our country will get its figs in future from the Pacific coast. The Division continues its study of injurious insects that may invade our territory from contiguous countries. Volunteer observers for this Division are studying injurious Puerto Rican insects. Sets of injurious insects are being received from several foreign countries with which we have intercourse. Insects are being studied that are destructive to forests in the Northwestern States. The life history of the San Jose scale, through the work of this Division and State officials, is now well understood. Experimentation in this Division to learn whether this scale would live on dried fruit has convinced most foreign importers that they may safely handle this product.

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One explorer went to Japan to procure varieties of rice possessing high milling qualities, for cultivation under the new system in Louisiana and Texas, by which the rice fields can be flooded when necessary and dried at pleasure to admit the harvester. A testing garden has been secured on the Potomac flats, through the courtesy of the War Department, where observation may be had of plants introduced from foreign countries, so as to avoid new plant diseases. The acquisition of tropical islands by the United States has brought many inquiries to this Division regarding the cultivated plants of the Tropics. There is now widespread interest in tropical agriculture and a demand for correct information on the subject, which the Department must be prepared to satisfy.

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The crop belts have been found to conform to certain temperature conditions and to coincide with natural belts inhabited by particular kinds of animals and plants, so that their boundaries may be fixed by a study of the geographic distribution of our native species. The work of mapping the life belts can be done only by experienced field naturalists. Persons qualified by knowledge and experience are few and difficult to secure, regardless of compensation. The Department, owing to the limited means at its disposal, has not only been unable to increase the small force long engaged in this work, but has lost several assistants who have resigned to accept better positions elsewhere, for each year members of the Biological Survey are offered salaries much higher than those the Department is able to pay. No increase in the appropriation has been made for seven or eight years, as a consequence of which it is impossible to carry on the work as economically as could be done with a slightly larger and better equipped force. Much time is lost in fitting young and inexperienced assistants to replace those who resign to accept more profitable positions elsewhere; and it is often necessary to extend a piece of field work over several seasons which might be completed in a single season, with a considerable saving in expense.

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The diseases of trees are as a rule of such a nature as to necessitate much careful investigation to discover the causes. Some are due to unfavorable surroundings, such as soil or plant food, or to the presence of noxious substances in the soil and air. The little-peach disease in Michigan threatens to cripple the peach industry seriously unless some means of checking it are found. A scientist from this Division has been detailed to study the conditions and obtain all the light possible on this disease in Michigan and elsewhere. Definite conclusions have not been reached. The past summer has not been favorable for studying the disease, because during the severe winter of 1898-99 many trees partially diseased were killed outright.

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Experimentation under the direction of the Division is being conducted in North Carolina and Florida, with a view to the successful production of the finer table grapes of Europe. One hundred and nineteen varieties grafted on Phylloxera-resistant American stocks have been planted by the experimenters, as well as 43 varieties of "direct producers" and "resistant stocks." These vines were imported through the Section of Seed and Plant Introduction, and more varieties will be added during the coming year, so as to have thorough and comprehensive tests made of all varieties likely to be useful. A better knowledge of fungous diseases at the present time gives hope that we can produce these fine grapes more successfully than was done a number of years ago, before the science of applying fungicides was so well understood. The results of experiments in root-grafting by this Division are being prepared for publication.

A catalogue of fruits recommended for cultivation in various sections of the United States by the American Pomological Society, which was published in 1897, has been thoroughly revised by a committee of that society working in cooperation with the divisional force. To secure more definite data regarding the adaptability of varieties on the Pacific coast, Prof. E. J. Wickson, of the University of California, was last year appointed a special agent to conduct special investigations on the subject among the growers of that region. Extended preliminary investigations of the conditions of the fruit industry in Idaho, eastern Oregon, and western Washington were made by the Pomologist during the autumn of 1898. The fruit industry as a commercial enterprise is comparatively new in both these sections. The outlook for the commercial fruit grower there is very promising.

The unusually low temperature reached in 1899 worked permanent injury to the trees and vines in many sections. Many that were supposed to be hardy have been killed outright in many localities. The Division of Pomology is endeavoring to ascertain the facts with regard to varieties, so that it may be able to make recommendations for certain localities.

In preparing a horticultural exhibit for the Paris Exposition the Division will secure such fruits especially as are now in demand or may find a market in foreign countries. Canned, dried, and evaporated fruits and vegetables will be shown in great variety. The apple and the orange will be prominent among fresh fruits, and the pecan

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Experimentation under the direction of the Division is being conducted in North Carolina and Florida, with a view to the successful production of the finer table grapes of Europe. One hundred and nineteen varieties grafted on Phylloxera-resistant American stocks have been planted by the experimenters, as well as 43 varieties of "direct producers" and "resistant stocks." These vines were imported through the Section of Seed and Plant Introduction, and more varieties will be added during the coming year, so as to have thorough and comprehensive tests made of all varieties likely to be useful. A better knowledge of fungous diseases at the present time gives hope that we can produce these fine grapes more successfully than was done a number of years ago, before the science of applying fungicides was so well understood. The results of experiments in root-grafting by this Division are being prepared for publication.

A catalogue of fruits recommended for cultivation in various sections of the United States by the American Pomological Society, which was published in 1897, has been thoroughly revised by a committee of that society working in cooperation with the divisional force. To secure more definite data regarding the adaptability of varieties on the Pacific coast, Prof. E. J. Wickson, of the University of California, was last year appointed a special agent to conduct special investigations on the subject among the growers of that region. Extended preliminary investigations of the conditions of the fruit industry in Idaho, eastern Oregon, and western Washington were made by the Pomologist during the autumn of 1898. The fruit industry as a commercial enterprise is comparatively new in both these sections. The outlook for the commercial fruit grower there is very promising.

The unusually low temperature reached in 1899 worked permanent injury to the trees and vines in many sections. Many that were supposed to be hardy have been killed outright in many localities. The Division of Pomology is endeavoring to ascertain the facts with regard to varieties, so that it may be able to make recommendations for certain localities.

In preparing a horticultural exhibit for the Paris Exposition the Division will secure such fruits especially as are now in demand or may find a market in foreign countries. Canned, dried, and evaporated fruits and vegetables will be shown in great variety. The apple and the orange will be prominent among fresh fruits, and the pecan

and shagbark among nuts. Everything is being done along these lines to inform the world regarding our marketable products and to assist merchants in finding markets.

DIVISION OF FORESTRY.

The work of this Division has been entirely reorganized during the year. This and the introduction of practical and paying forestry among lumbermen on a large scale, the extensive investigations in tree planting, preparatory to practical work with tree planters, and the widespread interest and cooperation in the work, especially among lumbermen, are the most important facts to be reported. A striking instance of this cooperation is the action of the redwood lumbermen of San Francisco, who voted to subscribe $1,000, and offered free transportation and free subsistence in their camps to our agents, so as to advance by one year the time when the Division, delayed by lack of funds, could begin work on the growth and reproduction of the redwood.

Notwithstanding the increased appropriation made by the last Congress, it is still utterly impossible to cover the field of necessary action. Very many demands made for work of great importance to the preservation and proper use of forests in the United States can not be complied with for lack of means. It is earnestly hoped that the Division may be enabled during the next fiscal year, through a largely increased appropriation, to take advantage of the unprecedented opportunities created by the rapid public awakening to the meaning and value of practical forestry.

At present all work in the Division is assigned to four sections, each one in charge of a man of special knowledge and qualifications. These are: The section of working plans, which has charge of all practical work in the woods; that of economic tree planting; that of special investigations, dealing with the habits and characteristics of trees which affect their use in practical forestry; and that of office work. But two of the various grades of technical assistants under the heads of sections require mention here.

COLLABORATORS AND STUDENT ASSISTANTS.

The first grade is that of collaborator. The collaborators are experts of established reputation on forestry, lumbering, or tree planting, and are scattered throughout the country. They prepare and forward for publication treatises on subjects previously agreed upon. Through them the best experience of trained specialists becomes available to the Division at a very moderate cost. The pay of a collaborator is $300 a year.

The grade of student assistant was created to provide trained men for the future needs of the Division and to supply it immediately with assistants of high intelligence at small cost. Twenty-eight of these assistants have been employed during the summer, the majority of whom are college or university men. Only those who have declared their intention to adopt forestry as their profession are received. In the field they work under the supervision of trained foresters, especially in the preparation of working plans and the study of commercial trees. The pay of a student assistant is $25 per month.

Both collaborators and student assistants have been of marked value to the work of the Division.

PRACTICAL ASSISTANCE TO FARMERS, LUMBERMEN, AND OTHERS.

Last October a circular was issued (No. 21 of the Division of Forestry) offering advice and practical assistance to farmers, lumbermen, and others in handling their forest lands, with a view of bringing about the substitution of conservative for destructive methods. This offer provided for the preparation of working plans, with full directions for work and with practical assistance on the ground, without cost to the owners of wood lots, but in the case of larger tracts requiring the owners to meet expenses for travel and subsistence, and for the necessary helpers for the agents of the Division while in the field.

During the year applications were received from 123 owners in 35 States for the management of 1,513,592 acres. Of these applications, 48 were for large tracts covering together 1,506,215 acres, the remainder being for wood lots.

Personal attention on the ground was given to 41 tracts, covering about 400,000 acres in 19 States. The contribution of private owners to the expenses of this work was about $3,000.

It was found possible for the owners of a majority of these tracts to carry out the working plans without personal assistance, but 15 of them required the active participation of the Division. On two of the latter, comprising 108,000 acres, the working plans were put into execution early in the year, and the first year's work has been successfully completed. The second year's work is being pursued under very favorable conditions.

As a result of a calculation, based on exact measurements, of the amount of lumber wasted by the prevailing practice of cutting high spruce stumps in the Adirondacks, there has been a decided change for the better on certain tracts, and at the same time a great reduction in the amount of young spruce cut for road building has been brought about. These are important changes.

In connection with the preparation of the working plans for the two large tracts in the Adirondacks, a special study has been made of the growth and production of the spruce on the eastern side of the mountains and of birch and maple on the western slope.

Of the total amount of land submitted for working plans, about 1,200,000 acres have not yet been examined. These tracts will be considered during the ensuing year as fast as the very inadequate force of the Division will permit, and working plans will be made for a selected number.

The Division has been thoroughly equipped with instruments for field work, in which it was wholly lacking at the beginning of the year.

COMMERCIAL TREES.

During the year five species of commercially valuable trees have been studied to determine their rate of growth and to ascertain their special qualities in forestry. The more important of these studies relate to the loblolly pine, in North Carolina, a tree of the first economic importance, and the red fir in Washington, also called Douglas fir, yellow fir, Oregon pine, etc., one of the most valuable and widely distributed trees of the world. These studies have met with the cordial approval of lumbermen, and much practical assistance has been rendered by them. In addition the study of the coast redwood in California has recently been begun, and later, if enough money can be saved for that purpose, the white oak and the hickories will be taken up.

ECONOMIC TREE PLANTING.

The planting of experimental plats in cooperation with State agricultural experiment stations has been discontinued, and the stations have taken over the plantations and assumed the responsibility for them. This was done after a thorough study of the old plan, after careful examination of the plantations at nine of the eleven stations, and with the acquiescence of the authorities of every station. Two other lines of work have taken the place of experimental tree planting. One is a careful study of the results of the planting already done, in which all the species used in the cooperative plantations are represented, and from which practically all the results to be expected from them after many years may be gathered without delay and far more cheaply; and the other the giving of practical assistance to tree planters under the terms of an offer (set forth in Circular No. 22, Division of Forestry) similar to that made to forest owners.

Close relations have been established with five of the most competent men in the treeless regions, and these gentlemen are preparing reports on subjects of direct interest to tree planters.

In addition to the studies now being pursued, the work of the present year will in great measure be devoted, first, to giving practical assistance to tree planters in the selection of the proper trees to plant and in planting them rightly, and, secondly, to an attempt to determine the true effect of bare and wooded or brush-covered slopes on the run-off of streams. The vast interests affected by the solution of this difficult problem will justify the most persistent and careful work.

SPECIAL INVESTIGATIONS.

Forest fires have been studied historically and in the field, and important results have been reached. Records of more than 5,000 fires have been compiled and classified, and field work has been prosecuted in seven States.

A series of studies of North American forests by experts with special knowledge of definite localities is in progress, and it is expected that three of them will be completed during the coming winter.

Historical studies of the progress in forestry in New Jersey, Massachusetts, and other States have been begun, and those for New York are practically completed.

Much material has been collected for a general account of the progress of forestry in the United States and of the practical application of conservative forest treatment in this country up to the present time.

Noteworthy progress has been made during the year in the photographic forest description of the United States.

OFFICE WORK.

The mailing list has been revised and extended, especially among newspapers, and much material for publication has accumulated and awaits attention during the winter. The botanical work formerly carried on by this Division has been turned over to the Division of Botany, where it more properly belongs.

During the year the force has been much increased, largely by the addition of young American foresters. At its highest, the total membership was more than five times that at the beginning of the last fiscal year.

PLANS FOR THE ENSUING YEAR.

Except for the new work referred to above, the plans of the Division, which have received my approval, do not contemplate any material changes from the lines of effort pursued in the year just past.

DIVISION OF SOILS.

FIELD OPERATIONS.

The Division of Soils has continued and considerably extended the investigation and mapping of the alkali soils of the irrigated districts of the West, mentioned in my last report, with results which are at once interesting and practically important to the irrigation farmer. Three field parties have been out during the season mapping a small area in the Yellowstone Valley in Montana; also about 150 square miles in the Pecos Valley, New Mexico, and 250 square miles in the vicinity of Salt Lake City, Utah, with a reconnoissance over a much larger area. Short circulars are being prepared for immediate and wide circulation calling attention to the conditions due to, and the best measures to prevent injury from, alkali or seepage water, as well as the best means for the reclamation of injured or abandoned lands. Fuller reports will then be prepared, with detailed soil and alkali maps on a scale of an inch to the mile, to be published in a volume covering the field operations of the Division during this year.

The trouble from alkali is due primarily to the large amounts of soluble salts generally present in all soils of an arid region. The rainfall is not sufficient to carry off the salts as they are set free in the decomposition of the rocks. These salts are naturally distributed throughout the soil, and for a few years are not harmful. With the application of irrigation water, however, in the intensive cultivation of crops, the excess of water accumulates and is liable to fill up the subsoil, and this, together with the rapid evaporation in an arid climate, shifts the salts until they gradually accumulate at or near the surface in such quantities as to be beyond the endurance of crops. The natural drainage has of course a great influenee on such an accumulation of both seepage waters and alkali.

Another, and perhaps the most important, cause of the rise of the subsoil water and accumulation of alkali is in the leakage or seepage from canals. As such damage is liable to be widespread, it is a matter for serious consideration whether canal companies should not be required to protect their ditches from undue loss, and individuals be restrained from overirrigation or made liable for damages in civil suits.

Another source of trouble is in the use of water for irrigation containing too large a salt content. Cases have been brought to my attention where land companies have, through extensive advertising, attracted many settlers, only to deliver water which the companies had previously been informed contained too much alkali for irrigation. Such action only invites widespread suffering and loss to the settlers.

In some districts the condition of the water can be controlled, in a large measure, by the water companies. Reservoirs are frequently lowered for repairs or for cleaning out at the beginning of a long dry period, and the remaining water concentrates by evaporation until it is really unfit for irrigation if the inflow is small and the usual floods are delayed. Furthermore, the first flood after a long dry spell often brings down great quantities of alkali, which have accumulated on the watershed during the dry season. Frequently these first flood waters should be diverted from the reservoirs, in order to prevent serious damage to the community.

These matters are clearly set forth in the report of the chief of the Division of Soils and in his statement of the field operations of the Division, to which attention is called.

RECLAMATION OF ALKALI LANDS.

When the alkali contains considerable quantities of carbonate of soda, the usual remedy is heavy applications of gypsum with drainage, if necessary, to insure thorough aeration of the land. When the other alkali salts or seepage waters have accumulated in excessive quantities, drainage is necessary.

So sudden and unexpected is the damage from the rise of seepage waters and alkali that estates worth thousands of dollars may have to be abandoned in two or three years, with an utter depreciation of value. So widespread is the damage that in one tract alone near Salt Lake City there are 100 square miles of practically abandoned land, partly within the city limits, formerly containing some of the most fertile lands of the valley, which would have, under a conservative estimate, a value of over $3,000,000 if the original conditions could be restored. With the encroachment of the alkali the farmers are moving back on the higher levels.

The matter of artificial drainage, as a means of preventing damage and of reclaiming alkali lands, has been so often advocated without attracting the attention necessary to induce action, and the matter is of such vital importance to the West, that I have recommended to Congress an appropriation of $10,000 for the purpose of actually demonstrating the practical utility of the different methods of treating such lands.

SOIL MAPPING IN THE EAST.

Equally important work is being done in the eastern district of the country. Part of this will be referred to under "Tobacco investigations."

The methods of field soil surveys have been worked out in the past few years in this Department, and men have been carefully trained for such work. As no such training exists elsewhere in this country, several of the experiment stations and State geological and economic surveys have been glad to avail themselves of the cooperation of the Department, thus, while contributing to the expenses of the work, being relieved of the direction and responsibilities of making soil surveys of their States. Thus, a detailed soil survey has been undertaken of the soils of Maryland, in cooperation with the geological survey of that State, and of Louisiana, in cooperation with the State experiment station. Such cooperation will be encouraged so far as competent men can be obtained and the means at our disposal will permit. Other States are willing to contribute money, but the difficulty has been to obtain men and to find the time required to train them. There is a wide and valuable field in this work for the graduates of our agricultural colleges who are willing and able to undergo the necessary training.

TOBACCO INVESTIGATIONS.

The investigations of the tobacco soils of the country by the Division of Soils has shown so much of importance that last year I asked Congress for an appropriation to extend and supplement this work. This request was granted. The money was not available until the first of July, 1899, but since that time a large amount of the most important work has been done, which will be referred to in my next Annual Report. Briefly, this work includes the mapping of 400 square miles in the Connecticut Valley, including the principal tobacco areas of that important locality. This map, which is being prepared for publication, shows the character of the soils and their distribution.

The soils occur in more or less well-defined terraces, formed by the old lake which covered that area in prehistoric times. The highest terraces, or the old lake bottom, are coarse sand, containing fine gravel. These "plains" soils produce the finest wrapper leaf when the season is favorable, but on account of the droughty character of the section such crops are only obtainable about two years in five. Some practical method can no doubt be found to make the crop more certain.

The next lower terrace is of finer sand, and it is upon this that the general crop of Havana seed leaf is produced. The next terrace is of still finer sand and produces the fine broad-leaf variety, while the lowest terrace, or the present meadows, is of such fine silt that it produces a coarse dark tobacco unsuited to the present market demands. There are other soils upon which tobacco can not be grown, and still others upon which tobacco of peculiar properties is produced, suited to certain trade. The map will show these soils in different colors.

CAUSE OF THE FERMENTATION OF TOBACCO.

To supplement this soil work, the Division of Vegetable Physiology and Pathology is cooperating in the study of the cause of the fermentation of tobacco. It has been found that the flavor and aroma are due not to bacteria, as was formerly supposed, but to enzyms or oxidizing agents in the leaf itself. The formation of these oxidizing agents and the conditions of their greatest activity are being studied.

It has been found that some of the soils of the Connecticut Valley are similar in all essential respects to the soils of Florida and Cuba, and an effort will be made, through changes in the methods of cultivation and fermentation based upon these investigations, to improve the quality of the Connecticut leaf so as to adapt it better to the present demands for wrapper for high-priced cigars. Next year it is proposed to investigate the soils of Pennsylvania and Ohio to see if the quality of the filler leaf grown on the heavier soils of these localities can not be greatly improved.

PHYSICAL AND CHEMICAL INVESTIGATIONS.

To supplement and support the field work of the Division, various investigations are being carried on, partly with the cooperation of the Division of Chemistry, in relation to many intricate soil problems, such as the retention and movement of the water through soils; the physico-chemical effect of fertilizers in soils; the absorption of salts; the physical properties of loams and clays; the plasticity of clay; the formation of hardpan, and similar subjects.

These matters are exceedingly intricate and difficult to work out, but the vast importance of the economic problems depending upon these properties of soils justifies a prolonged and searching inquiry into them.

Several instruments and methods have been devised and perfected in the Division of Soils which are of distinct advantage in these lines of soil investigation. Furthermore, the very large and valuable collection of over 4,000 samples of soil supplies very valuable material for these laboratory investigations.

DIVISION OF AGROSTOLOGY.

NATIVE GRASSES.

It is acknowledged that there is no country in the world so rich in the number and variety of useful grasses and forage plants as the United States. The investigations of the Division of Agrostology have demonstrated that the country abounds in native species adapted to nearly every variety of soil and climate and to almost every requirement. There are upland and lowland varieties, there are woodland and prairie species, there are kinds which exist only in the humid regions along the coast, and there are others which thrive in the arid regions of the interior. Some are productive hay grasses or afford abundant grazing, while others again are valuable for fixing drifting sands or reclaiming impoverished or waste lands. There are decorative species for the garden or lawn, and not a few are useful in the arts and manufacture. Grasses are chiefly important, however, as food plants for all kinds of stock, yielding beef, mutton, and other animal products, which are a source of great wealth to the country, and their investigation along these lines is a most useful and essentially practical work of this Department. The fine quality of the forage afforded by the native grasses of our vast cattle ranges is a matter of world-wide comment; the perpetuation and improvement of the most valuable sorts are matters of extreme importance, and these may well be the subjects of practical scientific investigations at our hands.

COOPERATIVE EXPERIMENTAL WORK.

In addition to the continuation of the work already established in Texas, other experiments have been instituted during the year in the

of specialists can have a practical application. During the year 2,700 lots have been placed with about 275 experimenters in various portions of the country. Consul Merriam at Iquique has sent us a lime from the interior of Chile and a reputed hardy type of alligator pear. The last mentioned is being thoroughly tested in the Southern States. A reputed hardy variety from Mexico is also being experimented with.

Experimentation under the direction of the Division is being conducted in North Carolina and Florida, with a view to the successful production of the finer table grapes of Europe. One hundred and nineteen varieties grafted on Phylloxera-resistant American stocks have been planted by the experimenters, as well as 43 varieties of "direct producers" and "resistant stocks." These vines were imported through the Section of Seed and Plant Introduction, and more varieties will be added during the coming year, so as to have thorough and comprehensive tests made of all varieties likely to be useful. A better knowledge of fungous diseases at the present time gives hope that we can produce these fine grapes more successfully than was done a number of years ago, before the science of applying fungicides was so well understood. The results of experiments in root-grafting by this Division are being prepared for publication.

A catalogue of fruits recommended for cultivation in various sections of the United States by the American Pomological Society, which was published in 1897, has been thoroughly revised by a committee of that society working in cooperation with the divisional force. To secure more definite data regarding the adaptability of varieties on the Pacific coast, Prof. E. J. Wickson, of the University of California, was last year appointed a special agent to conduct special investigations on the subject among the growers of that region. Extended preliminary investigations of the conditions of the fruit industry in Idaho, eastern Oregon, and western Washington were made by the Pomologist during the autumn of 1898. The fruit industry as a commercial enterprise is comparatively new in both these sections. The outlook for the commercial fruit grower there is very promising.

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FIELD OPERATIONS.

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The trouble from alkali is due primarily to the large amounts of soluble salts generally present in all soils of an arid region. The rainfall is not sufficient to carry off the salts as they are set free in the decomposition of the rocks. These salts are naturally distributed throughout the soil, and for a few years are not harmful. With the application of irrigation water, however, in the intensive cultivation of crops, the excess of water accumulates and is liable to fill up the subsoil, and this, together with the rapid evaporation in an arid climate, shifts the salts until they gradually accumulate at or near the surface in such quantities as to be beyond the endurance of crops. The natural drainage has of course a great influence on such an accumulation of both seepage waters and alkali.

Another, and perhaps the most important, cause of the rise of the subsoil water and accumulation of alkali is in the leakage or seepage from canals. As such damage is liable to be widespread, it is a matter for serious consideration whether canal companies should not be required to protect their ditches from undue loss, and individuals be restrained from overirrigation or made liable for damages in civil suits.

Another source of trouble is in the use of water for irrigation containing too large a salt content. Cases have been brought to my attention where land companies have, through extensive advertising, attracted many settlers, only to deliver water which the companies had previously been informed contained too much alkali for irrigation. Such action only invites widespread suffering and loss to the settlers.

In some districts the condition of the water can be controlled, in a large measure, by the water companies. Reservoirs are frequently lowered for repairs or for cleaning out at the beginning of a long dry period, and the remaining water concentrates by evaporation until it is really unfit for irrigation if the inflow is small and the usual floods are delayed. Furthermore, the first flood after a long dry spell often brings down great quantities of alkali, which have accumulated on the watershed during the dry season. Frequently these first flood waters should be diverted from the reservoirs, in order to prevent serious damage to the community.

These matters are clearly set forth in the report of the chief of the Division of Soils and in his statement of the field operations of the Division, to which attention is called.

RECLAMATION OF ALKALI LANDS.

When the alkali contains considerable quantities of carbonate of soda, the usual remedy is heavy applications of gypsum with drainage, if necessary, to insure thorough aeration of the land. When the other alkali salts or seepage waters have accumulated in excessive quantities, drainage is necessary.

So sudden and unexpected is the damage from the rise of seepage waters and alkali that estates worth thousands of dollars may have to be abandoned in two or three years, with an utter depreciation of value. So widespread is the damage that in one tract alone near Salt Lake City there are 100 square miles of practically abandoned land, partly within the city limits, formerly containing some of the most fertile lands of the valley, which would have, under a conservative estimate, a value of over $3,000,000 if the original conditions could be restored. With the encroachment of the alkali the farmers are moving back on the higher levels.

The matter of artificial drainage, as a means of preventing damage and of reclaiming alkali lands, has been so often advocated without attracting the attention necessary to induce action, and the matter is of such vital importance to the West, that I have recommended to Congress an appropriation of $10,000 for the purpose of actually demonstrating the practical utility of the different methods of treating such lands.

SOIL MAPPING IN THE EAST.

Equally important work is being done in the eastern district of the country. Part of this will be referred to under "Tobacco investigations."

The methods of field soil surveys have been worked out in the past few years in this Department, and men have been carefully trained for such work. As no such training exists elsewhere in this country, several of the experiment stations and State geological and economic surveys have been glad to avail themselves of the cooperation of the Department, thus, while contributing to the expenses of the work, being relieved of the direction and responsibilities of making soil surveys of their States. Thus, a detailed soil survey has been undertaken of the soils of Maryland, in cooperation with the geological survey of that State, and of Louisiana, in cooperation with the State experiment station. Such cooperation will be encouraged so far as competent men can be obtained and the means at our disposal will permit. Other States are willing to contribute money, but the difficulty has been to obtain men and to find the time required to train them. There is a wide and valuable field in this work for the graduates of our agricultural colleges who are willing and able to undergo the necessary training.

TOBACCO INVESTIGATIONS.

The investigations of the tobacco soils of the country by the Division of Soils has shown so much of importance that last year I asked Congress for an appropriation to extend and supplement this work. This request was granted. The money was not available until the first of July, 1899, but since that time a large amount of the most important work has been done, which will be referred to in my next Annual Report. Briefly, this work includes the mapping of 400 square miles in the Connecticut Valley, including the principal tobacco areas of that important locality. This map, which is being prepared for publication, shows the character of the soils and their distribution.

The soils occur in more or less well-defined terraces, formed by the old lake which covered that area in prehistoric times. The highest terraces, or the old lake bottom, are coarse sand, containing fine gravel. These "plains" soils produce the finest wrapper leaf when the season is favorable, but on account of the droughty character of the section such crops are only obtainable about two years in five. Some practical method can no doubt be found to make the crop more certain.

The next lower terrace is of finer sand, and it is upon this that the general crop of Havana seed leaf is produced. The next terrace is of still finer sand and produces the fine broad-leaf variety, while the lowest terrace, or the present meadows, is of such fine silt that it produces a coarse dark tobacco unsuited to the present market demands. There are other soils upon which tobacco can not be grown, and still others upon which tobacco of peculiar properties is produced, suited to certain trade. The map will show these soils in different colors.

CAUSE OF THE FERMENTATION OF TOBACCO.

To supplement this soil work, the Division of Vegetable Physiology and Pathology is cooperating in the study of the cause of the fermentation of tobacco. It has been found that the flavor and aroma are due not to bacteria, as was formerly supposed, but to enzyms or oxidizing agents in the leaf itself. The formation of these oxidizing agents and the conditions of their greatest activity are being studied.

It has been found that some of the soils of the Connecticut Valley are similar in all essential respects to the soils of Florida and Cuba, and an effort will be made, through changes in the methods of cultivation and fermentation based upon these investigations, to improve the quality of the Connecticut leaf so as to adapt it better to the present demands for wrapper for high-priced cigars. Next year it is proposed to investigate the soils of Pennsylvania and Ohio to see if the quality of the filler leaf grown on the heavier soils of these localities can not be greatly improved.

PHYSICAL AND CHEMICAL INVESTIGATIONS.

To supplement and support the field work of the Division, various investigations are being carried on, partly with the cooperation of the Division of Chemistry, in relation to many intricate soil problems, such as the retention and movement of the water through soils; the physico-chemical effect of fertilizers in soils; the absorption of salts; the physical properties of loams and clays; the plasticity of clay; the formation of hardpan, and similar subjects.

These matters are exceedingly intricate and difficult to work out, but the vast importance of the economic problems depending upon these properties of soils justifies a prolonged and searching inquiry into them.

Several instruments and methods have been devised and perfected in the Division of Soils which are of distinct advantage in these lines of soil investigation. Furthermore, the very large and valuable collection of over 4,000 samples of soil supplies very valuable material for these laboratory investigations.

DIVISION OF AGROSTOLOGY.

NATIVE GRASSES.

It is acknowledged that there is no country in the world so rich in the number and variety of useful grasses and forage plants as the United States. The investigations of the Division of Agrostology have demonstrated that the country abounds in native species adapted to nearly every variety of soil and climate and to almost every requirement. There are upland and lowland varieties, there are woodland and prairie species, there are kinds which exist only in the humid regions along the coast, and there are others which thrive in the arid regions of the interior. Some are productive hay grasses or afford abundant grazing, while others again are valuable for fixing drifting sands or reclaiming impoverished or waste lands. There are decorative species for the garden or lawn, and not a few are useful in the arts and manufacture. Grasses are chiefly important, however, as food plants for all kinds of stock, yielding beef, mutton, and other animal products, which are a source of great wealth to the country, and their investigation along these lines is a most useful and essentially practical work of this Department. The fine quality of the forage afforded by the native grasses of our vast cattle ranges is a matter of world-wide comment; the perpetuation and improvement of the most valuable sorts are matters of extreme importance, and these may well be the subjects of practical scientific investigations at our hands.

COOPERATIVE EXPERIMENTAL WORK.

In addition to the continuation of the work already established in Texas, other experiments have been instituted during the year in the

States of Washington and South Dakota. The results obtained in Texas clearly demonstrate the possibility of materially improving worn-out pastures and ranges by practical methods of treatment. Tests have been made of a number of promising drought-resistant grasses and forage crops, and some of these have shown great hardiness, as, for example, some of the saltbushes, sorghums, and vetches, as well as such native varieties as Colorado grass, blue grama, black grama, and wild rye. On the Pacific coast. the most extended tests have been made at Walla Walla, Wash. Among the varieties giving best results at this point may be mentioned sainfoin, Australian saltbush, blue grama, smooth brome, Oregon rescue grass, slender wheat grass, Japanese barnyard millet, Turkestan alfalfa, and some of the vetches. Most of these varieties show characteristics which will render them adaptable to the conditions which prevail over large portions of the great range regions of the West and Northwest. Thus, smooth brome has exhibited great vitality, surviving prolonged drought as well as extreme cold, and affording good returns of pasturage, hay, and seed under conditions that would destroy the ordinary grasses; the saltbush promises to be of much value on land strongly impregnated with alkali, and blue grama and the wheat grasses seem destined to become our most valuable means for reclaiming the many thousands of acres of range lands that have been all but ruined by protracted droughts and overstocking.

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By means of these experiments we are learning that many of the native grasses adapt themselves readily to cultivation in our meadows and pastures, in some cases proving of more value than any of the introduced varieties yet tried. It is also being demonstrated that these native grasses are susceptible to improvement by careful cultivation and selection, and forms are being developed that give promise of much greater adaptability to farm conditions than the parent stocks.

There are many native leguminous forage plants, and some of these are also giving good results under cultivation. The Metcalfe bean of the table-lands of New Mexico is one of these. It not only does well in its native section, but has made excellent growth on the Pacific coast, and gives promise of being a valuable forage plant for the dry uplands of the West.

As in former years, most of the experimental work connected with the grass and forage plant investigations is carried on in cooperation

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PLANS FOR FUTURE WORK.

The great importance of the problems connected with the forage supply of our country—the close relation which it bears to the welfare and prosperity of the agricultural classes and the increase of public interest in grass and forage-plant investigations—make it imperative not only that the present lines of investigation should be continued, but that new ones be undertaken. The investigations under way in the Gulf-coast region and on the Pacific slope ought to be extended in their scope; the work on range improvement should be continued along the present practical lines; the investigations looking toward the preservation and improvement of our most valuable native grasses and forage plants should be continued; the study of soil and sand-binding grasses ought to be extended to include experiments as to the adaptability of our native sorts to practical use for fixing the shifting sands of our coasts and for holding embankments in place, as well as to the introduction of desirable foreign sorts; investigations relative to the introduction, cultivation, and management of improved pasture and forage crops on the abandoned farms of New England should be undertaken; the question of forage crops suitable to alkali soils is one of much importance to certain sections of the country, and should receive full and careful investigation. There is no question as to the value and importance of investigations along all the lines indicated, and an increase in the appropriation for the Division is recommended in order to effectively carry on the work.

OFFICE OF EXPERIMENT STATIONS.

RELATIONS OF THE DEPARTMENT TO THE STATIONS.

The relations of the Department of Agriculture to the experiment stations of the several States become closer every year. An increased amount of assistance is given every year to the State experiment stations to enable them to carry out work of a national character. Cooperative work between the Department and the stations is gradually increasing. The Department is consulted oftener regarding the organization and management of the stations, the choice of officers, the lines of work to be undertaken, the execution of special work, plans for station buildings, materials and apparatus required for use in connection with the different kinds of agricultural investigations, etc.

The Department has been able to bring some influence to bear against the frequent change of station officials, which has been too common in certain States. At the same time no effort has been made to interfere with the independence of each as a State institution. The farmers of the States are appreciating the stations more and

more, giving them attention, requiring better work, securing State funds, and interesting themselves in the management and supervision. This is having an excellent effect and resulting in better work for the communities in which they are located, all along the line.

NATIONAL AND STATE AID TO THE STATIONS.

The stations in all the States and Territories are visited regularly every year by officials of the Office of Experiment Stations, whose report is transmitted annually to Congress for the information of the national legislators. Where the experiment station is a part of the agricultural college of the State the connection has a beneficial influence on the course of instruction, as the work of the station in the interest of the locality has a tendency to better instruct the officers of the college engaged in teaching. There is much need that the endowment of the Federal Government should be supplemented by the State in nearly every case, and many of the States are appropriating money to enable the stations to extend their work. The erection of buildings for the colleges has often been done for the purpose of increasing the facilities for experiment-station work.

The printing of station bulletins in a number of the States is regularly done at the public expense, while some of the stations are unable to publish the results of their experimental work for want of means for the purpose. Experimentation has been begun in Alaska with the aid of national funds. In each of the States of Alabama, Connecticut, New Jersey, and New York a separate station is maintained wholly or in part by State funds. The Louisiana experiment station, supported for a number of years by the sugar planters, is now under the management of the State. Every year the sum of $720,000 is paid to the several stations by the National Government, while nearly $500,000 is paid by the States, individuals, communities, and as fees for analyses of fertilizer, etc.

THE FUNDS OF THE STATIONS.

It has happened occasionally that boards of trustees have diverted experiment station funds to college purposes. The opinion of the Attorney-General of the United States has been had on this subject. According to this opinion, no portion of the funds appropriated by Congress in accordance with the terms of the act of March 2, 1887, can be used, either directly or indirectly, for paying the salaries or wages of professors, teachers, or other persons whose duties are confined to administration, teaching, or other work connected with the course of instruction given in the colleges with which stations are connected, or in any other educational institution, nor should any other expenses connected with the work or facilities for instruction in school or college courses be paid from said fund.

THE STATIONS CENTERS OF INFORMATION FOR LOCAL REQUIREMENTS.

In the development of methods of investigation and special apparatus the Department can now accomplish much more than any one of the stations. On the other hand, the stations are, to an increasing extent, becoming centers of information and authority on the lines of work in which they have been engaged with special reference to the local requirements of agriculture, and in some instances the stations, through the liberality of State governments or connection with strong colleges and universities, are in better position than the Department to carry on investigations requiring the knowledge and skill of experts or expensive forms of special apparatus.

By recognizing the authority of the stations in their several localities, securing the services of their expert officers, and the use of special facilities at their command, it is believed that the Department may oftentimes most economically expend the funds intrusted to it by Congress for special investigations, and can at the same time devote the energies of its officers more fully and effectively to the large enterprises for the promotion of the science and practice of agriculture.

THE EXHIBIT AT THE PARIS EXPOSITION.

An exhibit of the publications of the stations and of the Office of Experiment Stations, with photographs and charts showing the buildings and equipment of the stations, special features of their work, an illustrated report on the history of the stations, and a collection of special devices for station work, with illustrations of notable results by means of models and otherwise, will be made at the Paris Exposition. Investigations in Alaska, in nutrition, and in irrigation, in charge of the Department, will also be included in this exhibit. The materials for the exhibit will be largely furnished by the stations.

NEED OF STATIONS IN THE NEW POSSESSIONS.

There is a pressing necessity for the establishment of experiment stations in Puerto Rico, Hawaii, and the Philippines. The newer and more intimate relations existing between these islands and the United States, the responsibility assumed by the United States regarding them, and the necessity for giving to the peoples of those islands information regarding their staple crops, their development, and the insect and bacteriological pests to which they may be liable, suggest the necessity of scientific investigation of everything pertaining to production. These stations will be needed in our island possessions much more than they are needed in our States and Territories. Special investigations along these lines will not take the place of permanent experiment stations.

There is no method of informing the tiller of the soil so valuable to him as to have practical scientists studying the conditions of production in his neighborhood. There is thus provided not only an object lesson, but the foundation of a farm literature. A local station should be placed in each of the groups, on land belonging to the Government, with buildings and equipments for field and laboratory investigations, for careful surveying of the agricultural capabilities and requirements of the lands, cooperative experiments with interested farmers, the dissemination under frank of bulletins of original and compiled information, and the holding of farmers' meetings in different localities for the diffusion of practical information.

In general, there should be a systematic effort to disseminate useful information on agricultural subjects among the people and to gain new knowledge which may be utilized for the benefit of the agriculture of those regions. Educational influences of this nature established among the peoples of the islands will not be the least potent influences in elevating them to higher intellectual levels. Fifteen thousand dollars could be wisely appropriated for Hawaii, $10,000 for the Philippines, and $5,000 for Puerto Rico. These stations for the present should be under the direction of the Secretary of Agriculture until such time as, under the benign influence of the United States, the people in the islands are thoroughly prepared to take charge of institutions of this kind and manage them for themselves.

INFORMATION REGARDING WORK OF THE STATIONS.

A series of Farmers' Bulletins, based on the work of the experiment stations, for the purpose of disseminating throughout the country information regarding the work of the stations, and thus to acquaint farmers in a general way with the progress of agricultural investigation, on its practical side, has been printed by the Office of Experiment Stations. The demand for this class of Farmers' Bulletins is growing very rapidly. The aim is to provide our farmers with a popular record of the progress of agricultural research.

WORK IN ALASKA.

Work is progressing in the establishment of an experiment station in Alaska. Prof. C. C. Georgeson, a thoroughly educated and practical experimenter, has been put in charge of the work. Headquarters for the present are established at Sitka, and a building is being erected there for the convenience of the scientists connected with the station work. Seeds have been distributed among different localities in Alaska, and measures instituted to obtain information regarding the crops, methods of cultivation, feeding of animals, and agricultural possibilities of the different regions.

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IRRIGATION INVESTIGATIONS.

BEGINNING OF THE WORK.

The first appropriation for irrigation investigations became available July 1, 1898. The literature of irrigation, especially that containing accounts of experimental inquiries, was collated and reviewed, and correspondence was had with experiment station officers, State engineers, and other experts who were devoting their energies to the study of irrigation problems in this country. A conference of station officers and engineers was held in Denver July 12 to 13, 1898, at which the needs of agriculture under irrigation were earnestly considered and much valuable advice regarding plans for the work of this Office was obtained.

As a result of this preliminary inquiry, it was determined to limit the work of this Office under the appropriation to two general lines: First, the collation and publication of information regarding the laws and institutions of irrigated regions in their relation to agriculture; and, second, the publication of all available information regarding the use of irrigation waters in agriculture, as determined by actual experience of farmers and experimental investigators, and the encouragement of further investigations in this line by the experiment stations. Prof. Elwood Mead, State engineer of Wyoming, was asked to undertake the direct management of the investigations in charge of this Office. Two irrigation bulletins were completed within the fiscal year for which the appropriation was made. A report was also made to Congress on the usefulness of storage reservoirs as a part of the irrigation system. Thirty-five thousand dollars have been appropriated by Congress for the work of the present year, measures have been taken to organize the work on a more permanent basis, and an expert force with sufficient clerical assistance has been formed. The subjects requiring investigation are numerous. The conditions and needs of different localities vary, and the demand on the part of the people for more immediate information in so many lines is so urgent that much attention will have to be given to the selection of lines of work to be undertaken.

NEED OF EXPERTS.

One great difficulty is to find an adequate number of men who have had proper training to fit them to prepare publications or carry on investigations in the manner which our work requires. As a rule, the men who are best fitted for this work are engaged in other enterprises and can not be induced to enter the Department's service on the terms necessarily imposed. In this, as in other special lines of investigation which the Department has undertaken, it will be necessary to organize a force to work under the immediate direction of the expert in charge, and some time must elapse before this force can herbarium and nearly 4,000 determinations have been made for correspondents.

PLANS FOR FUTURE WORK.

The great importance of the problems connected with the forage supply of our country—the close relation which it bears to the welfare and prosperity of the agricultural classes and the increase of public interest in grass and forage-plant investigations—make it imperative not only that the present lines of investigation should be continued, but that new ones be undertaken. The investigations under way in the Gulf-coast region and on the Pacific slope ought to be extended in their scope; the work on range improvement should be continued along the present practical lines; the investigations looking toward the preservation and improvement of our most valuable native grasses and forage plants should be continued; the study of soil and sand-binding grasses ought to be extended to include experiments as to the adaptability of our native sorts to practical use for fixing the shifting sands of our coasts and for holding embankments in place, as well as to the introduction of desirable foreign sorts; investigations relative to the introduction, cultivation, and management of improved pasture and forage crops on the abandoned farms of New England should be undertaken; the question of forage crops suitable to alkali soils is one of much importance to certain sections of the country, and should receive full and careful investigation. There is no question as to the value and importance of investigations along all the lines indicated, and an increase in the appropriation for the Division is recommended in order to effectively carry on the work.

OFFICE OF EXPERIMENT STATIONS.

RELATIONS OF THE DEPARTMENT TO THE STATIONS.

The relations of the Department of Agriculture to the experiment stations of the several States become closer every year. An increased amount of assistance is given every year to the State experiment stations to enable them to carry out work of a national character. Cooperative work between the Department and the stations is gradually increasing. The Department is consulted oftener regarding the organization and management of the stations, the choice of officers, the lines of work to be undertaken, the execution of special work, plans for station buildings, materials and apparatus required for use in connection with the different kinds of agricultural investigations, etc.

The Department has been able to bring some influence to bear against the frequent change of station officials, which has been too common in certain States. At the same time no effort has been made to interfere with the independence of each as a State institution. The farmers of the States are appreciating the stations more and

more, giving them attention, requiring better work, securing State funds, and interesting themselves in the management and supervision. This is having an excellent effect and resulting in better work for the communities in which they are located, all along the line.

NATIONAL AND STATE AID TO THE STATIONS.

The stations in all the States and Territories are visited regularly every year by officials of the Office of Experiment Stations, whose report is transmitted annually to Congress for the information of the national legislators. Where the experiment station is a part of the agricultural college of the State the connection has a beneficial influence on the course of instruction, as the work of the station in the interest of the locality has a tendency to better instruct the officers of the college engaged in teaching. There is much need that the endowment of the Federal Government should be supplemented by the State in nearly every case, and many of the States are appropriating money to enable the stations to extend their work. The erection of buildings for the colleges has often been done for the purpose of increasing the facilities for experiment-station work.

The printing of station bulletins in a number of the States is regularly done at the public expense, while some of the stations are unable to publish the results of their experimental work for want of means for the purpose. Experimentation has been begun in Alaska with the aid of national funds. In each of the States of Alabama, Connecticut, New Jersey, and New York a separate station is maintained wholly or in part by State funds. The Louisiana experiment station, supported for a number of years by the sugar planters, is now under the management of the State. Every year the sum of $720,000 is paid to the several stations by the National Government, while nearly $500,000 is paid by the States, individuals, communities, and as fees for analyses of fertilizer, etc.

THE FUNDS OF THE STATIONS.

It has happened occasionally that boards of trustees have diverted experiment station funds to college purposes. The opinion of the Attorney-General of the United States has been had on this subject. According to this opinion, no portion of the funds appropriated by Congress in accordance with the terms of the act of March 2, 1887, can be used, either directly or indirectly, for paying the salaries or wages of professors, teachers, or other persons whose duties are confined to administration, teaching, or other work connected with the course of instruction given in the colleges with which stations are connected, or in any other educational institution, nor should any other expenses connected with the work or facilities for instruction in school or college courses be paid from said fund.

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THE STATIONS CENTERS OF INFORMATION FOR LOCAL REQUIREMENTS.

In the development of methods of investigation and special apparatus the Department can now accomplish much more than any one of the stations. On the other hand, the stations are, to an increasing extent, becoming centers of information and authority on the lines of work in which they have been engaged with special reference to the local requirements of agriculture, and in some instances the stations, through the liberality of State governments or connection with strong colleges and universities, are in better position than the Department to carry on investigations requiring the knowledge and skill of experts or expensive forms of special apparatus.

By recognizing the authority of the stations in their several localities, securing the services of their expert officers, and the use of special facilities at their command, it is believed that the Department may oftentimes most economically expend the funds intrusted to it by Congress for special investigations, and can at the same time devote the energies of its officers more fully and effectively to the large enterprises for the promotion of the science and practice of agriculture.

THE EXHIBIT AT THE PARIS EXPOSITION.

An exhibit of the publications of the stations and of the Office of Experiment Stations, with photographs and charts showing the buildings and equipment of the stations, special features of their work, an illustrated report on the history of the stations, and a collection of special devices for station work, with illustrations of notable results by means of models and otherwise, will be made at the Paris Exposition. Investigations in Alaska, in nutrition, and in irrigation, in charge of the Department, will also be included in this exhibit. The materials for the exhibit will be largely furnished by the stations.

NEED OF STATIONS IN THE NEW POSSESSIONS.

There is a pressing necessity for the establishment of experiment stations in Puerto Rico, Hawaii, and the Philippines. The newer and more intimate relations existing between these islands and the United States, the responsibility assumed by the United States regarding them, and the necessity for giving to the peoples of those islands information regarding their staple crops, their development, and the insect and bacteriological pests to which they may be liable, suggest the necessity of scientific investigation of everything pertaining to production. These stations will be needed in our island possessions much more than they are needed in our States and Territories. Special investigations along these lines will not take the place of permanent experiment stations.

There is no method of informing the tiller of the soil so valuable to him as to have practical scientists studying the conditions of production in his neighborhood. There is thus provided not only an object lesson, but the foundation of a farm literature. A local station should be placed in each of the groups, on land belonging to the Government, with buildings and equipments for field and laboratory investigations, for careful surveying of the agricultural capabilities and requirements of the lands, cooperative experiments with interested farmers, the dissemination under frank of bulletins of original and compiled information, and the holding of farmers' meetings in different localities for the diffusion of practical information.

In general, there should be a systematic effort to disseminate useful information on agricultural subjects among the people and to gain new knowledge which may be utilized for the benefit of the agriculture of those regions. Educational influences of this nature established among the peoples of the islands will not be the least potent influences in elevating them to higher intellectual levels. Fifteen thousand dollars could be wisely appropriated for Hawaii, $10,000 for the Philippines, and $5,000 for Puerto Rico. These stations for the present should be under the direction of the Secretary of Agriculture until such time as, under the benign influence of the United States, the people in the islands are thoroughly prepared to take charge of institutions of this kind and manage them for themselves.

INFORMATION REGARDING WORK OF THE STATIONS.

A series of Farmers' Bulletins, based on the work of the experiment stations, for the purpose of disseminating throughout the country information regarding the work of the stations, and thus to acquaint farmers in a general way with the progress of agricultural investigation, on its practical side, has been printed by the Office of Experiment Stations. The demand for this class of Farmers' Bulletins is growing very rapidly. The aim is to provide our farmers with a popular record of the progress of agricultural research.

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When the Department requires soil physicists, plant pathologists, or scientists well informed regarding animal husbandry and irrigation, it has been found almost impossible to get them. The Western agricultural colleges, where scientific knowledge of the facts concerning irrigation is most imperatively necessary, are making vigorous efforts to educate along these lines. The boards of management of the stations have been led to see the importance of the work in irrigation which the Department has undertaken, and are moving in the direction of the employment of a large number of competent investigators who can work in cooperation with the Department. There must be a period in which the training of experts, both by the Department and the experiment stations, will be the most important features.

REASONS FOR A GENERAL STUDY OF THE SUBJECT.

The need of an impartial and thorough study of water rights and the laws and methods of enforcing them is so urgent that the Department has been under continuous pressure from the people of the arid States to devote all the funds for irrigation investigations to this branch of the subject. The immense area embraced in the irrigated regions, the wide difference between the laws and methods of the different States, and the complexity and number of the problems to be considered have required the expenditure of a great deal of time and thought in the organization of this investigation. It is the intention, if sufficient provision is made, to include all the arid and semiarid States in this study during the coming year. In each of these States the law and methods differ widely. Even where conditions are of a similar nature, titles to water and methods of distribution are wholly unlike.

There is a second reason for making the investigation general. Many most important rivers are interstate streams. Some of them are used for irrigation in half a dozen different States. The water rights of these several States deal with a common supply. They vary so widely in their character that there must sooner or later come a time when their differences must be reconciled, or at least be brought to the attention of the Federal Government, and become a subject of legislation by Congress. It is of the utmost importance that before either of these things occurs there should be a thorough understanding of the character of the rights which are vested under these laws and of the disturbances which will ensue if a uniform or interstate system of water rights should be put in force. It is only through the collection and publication of these facts that either the several States or Congress can intelligently determine whether or not the control of rivers used in irrigation should be left exclusively to the States, as is done at present, or whether the present practice should be overturned and the streams be divided under the operation of federal laws and under the control of federal officials.

Measurements of the actual volume of water used in irrigation and the time of such use are being carried on in fifteen States and Territories. An approximate knowledge of the quantity of water required to irrigate an acre of land growing any given crop is sooner or later a necessity in any irrigated district. Farmers, canal builders, water commissioners, State lawmakers, and Congress all need this information in the making of water contracts, the planning of works, and the determination and protection of rights in streams. Without it all these important transactions are largely based on conjecture. The mistakes to which this gives rise are a serious obstacle to the conservation of the water supply and its orderly division.

It is the purpose of this investigation to begin the collection of this information, but in order that it may have general acceptance and value the facts secured must embrace a wide range of conditions and crops and be continued through a series of years, in order that accidental variations of seasons may be eliminated. Before the investigation is ended it is expected that it will embrace a study of more economical methods and a determination of the extent to which the reclaimed area can be extended thereby; but at the outset it is desired to ascertain what is the common practice of irrigators.

The method of measurement adopted had to take into consideration the fact that the demands of crops are not the same during different seasons of the year, nor is the supply uniform. Streams rise and fall. The adoption of any device for delivering a uniform flow would not, therefore, meet the demands of either the users of water or the character of the supply. What has been done has been to provide for keeping a constant record of the amount used, without any regard to the intentional variations in use or the accidental changes in the supply. To do this it has been arranged to measure the depth of water passing over a weir or flowing through a flume, and from this record to compute the amount of water used.

One object of the studies on the duty of water is to secure greater economy in its use, the reclamation of an increased area, and a larger yield of crops through its more skillful application. Something more is necessary than measurement of the quantity employed. The factors which tend to produce a high or low duty must also be studied. These include the amount of rainfall, records of temperature, rate of evaporation, character of soil, losses in transportation in canals, the merits of different methods of distributing water over the land,

and the influence which is exerted by the character of private water-right contracts for delivering water or of State laws governing titles thereto.

Before we can rightly estimate the value of reservoirs we must know not only the amount of water required by different crops, but the time when such water is needed. The purpose of reservoirs is to bring fluctuations in stream flow into harmony with the variations in the demands of crops. A dependence on the natural flow of many Western rivers permits of only a small fraction of their natural discharge being utilized, because the waters run to waste before or after they are needed. We must know when the water is needed, and how much is needed in different months of the year, before we can rightly estimate how much must be stored in order to utilize the entire supply.

The character of water-right contracts has much to do with the economy or waste which prevails in irrigation. Many of these contracts have been prepared by people having little practical knowledge of the subject. Among the classes of contracts which have been productive of either discontent or abuses are, first, perpetual water rights. Under these contracts the user pays a certain amount per acre for all the land on the canal, whether he irrigates it or not. These contracts usually specify a certain duty which has been fixed before the needs of the lands or the crops to be cultivated were known. Sometimes this duty is so low as to be a direct incentive to waste; in others, so high as to be manifestly one-sided and unfair.

A second class of contracts comprises those for the delivery of the water used at a specified rate per acre, without regard to the economy or waste of the irrigator. These contracts lead to controversies, because of the temptation on the part of the irrigator to use all he can, regardless of his necessities, since in that way he gets more for his money; while on the part of the canal owner the temptation is to agree to provide water for as many acres as he can without regard to his ability. The objections to these two classes of contracts are leading to the evolution of a new system in which payment is made for the quantity of water used.

The usefulness of this investigation is not limited to the arid region. On the contrary, there is no question but that irrigation can be profitably employed in the cultivation of large areas in the Eastern and Southern States. A hundred thousand acres of sugar land are being irrigated in Louisiana. Irrigation of the rice fields in the Carolinas is very extensive. The market gardener could profitably use irrigating waters. Irrigation is being experimented with in the growing of tea in South Carolina. Prof. E. B. Voorhees, of the New Jersey Agricultural Experiment Station, is collecting data on the area of land now irrigated in that State, the methods employed, the duty of water obtained, and the benefits received.

Many of the valleys of the mountain States are being injured seriously by the injudicious use of water. Wherever the soil contains alkali, it is being brought to the surface when too much water is applied, and the land thereby rendered infertile.

More than one-third of the country depends upon the success of irrigation to maintain the people, the industries, and the political institutions of that area, and future growth will also be measured by the increase of the reclaimed area. In a region which, in the extent and diversity of its mineral wealth, has no equal on the globe, the riches of the mines in the hills are already surpassed by the productions of the irrigated farms in the valleys, and the nation at large is at last awakening to the fact that the development of the use of the rivers and arid lands of the West will constitute one of the most important epochs in our increase in population and material wealth.

It is not possible at the present time for the owner of an irrigated farm to know exactly what his right is. The nation has made no provision for the distribution of either the natural flow of the streams or the stored water. The States vary greatly in their enactments regarding the use of water. If the control of this element of production is to be left to the States, there should be a definite declaration to that effect. If it is to be assumed by the General Government, it should be done at once.

OFFICE OF PUBLIC ROAD INQUIRIES.

INQUIRIES REGARDING ROAD-MAKING MATERIAL, ETC.

Something has been done during the past year by the Office of Public Road Inquiries to ascertain what can be accomplished in making roads by the use of the material found in the several States. Cooperation has been had with the experiment stations of several States in making steel roads, macadamized roads, and gravel roads. The people of all the States are very much interested in the improvement of their public highways. There is a great demand upon the Department of Agriculture for assistance in road making, in addressing the students at our agricultural colleges, and in giving instruction regarding the best methods of using what material may be found convenient. Publications have been sent out from the Department covering the several features of road making, and for these there is great demand. Much attention is being given to this subject by the legislatures of the several States of the Union.

I am of the opinion that it would be wise to have the resources of the Eastern, Southern, Middle, and Western States carefully inquired into by the appointment of competent men in each of these sections who would ascertain and report upon the road-making material obtainable, and at the same time give instruction in the actual construction of roads. There is also a necessity for scientific inquiry into the composition of road material in the several sections of our country, and the facility with which these materials when brought together combine to make good highways. Many sections of our country have within reach hard rock from which good roads can be made. Other sections are entirely lacking in this regard, and must, in my opinion, eventually look to steel tracks for supplying permanent good roads.

In order to get information along these lines, short sections of steel track were laid during the past year at Omaha, Nebr., Ames, Iowa, and St. Anthony Park, Minn. The Western States are not well supplied with stone and gravel for road-making purposes, and the people of these States are watching these experiments with great interest. It is our intention to encourage the laying down of steel-track sections during the coming year wherever we can induce the localities to purchase the steel. We do not yet know what is the best shape for the steel rail, nor do we know the best material to lay between the tracks, but inquiry is being made along these lines and information is being gathered from experience.

The people of the United States have associated themselves into national and State organizations for the purpose of encouraging the building of better roads and for the consideration of ways and means to that end. There is a great deal of agitation and considerable education along road-making lines. The people of many localities are exceedingly anxious to have the cooperation of the Department in improving their roads, and demands of this kind are so numerous that our limited force is entirely inadequate to give the assistance required. The object-lesson road work of the year has been as extensive in territory covered as it has been far-reaching in results accomplished. Model roads of various kinds have been built, under the supervision of agents of the Office of Public Road Inquiries, in Maryland, Nebraska, Minnesota, Iowa, Kentucky, Indiana, and Wisconsin. Elementary knowledge of road making is being rapidly spread among the people. Students at our colleges are taking a great interest in the study of road making. Gentlemen of means, enterprise, and public spirit are doing much along experimental lines for the education of their neighbors.

PRINCIPAL INQUIRIES OF THE YEAR.

The principal inquiries during the year were upon the following subjects: New road legislation, especially as regards State aid; the use of convict labor in road building or in the preparation of road material; experiments with steel roads and other new plans; methods of raising road funds; conditions of new roads under wear, especially the sample roads designed by officers of the Office of Public Road Inquiries; the promotion of rural free delivery of mails by good roads; the progress of organizations for road improvement; the prospects for road construction in several localities. The invention of road graders for use in the great productive prairies of the West has simplified the construction of roads more than any other one feature of progress. The value of these graders in making roads by horsepower is not well understood in all parts of the United States.

RECOMMENDATION.

The great activity on this line among the people of the United States during this fall, and the necessity of getting facts for use in the several localities of our country, induce me to recommend that Congress increase the appropriations of this Office sufficiently to justify the appointment of four experts, so that information can be gathered regarding valuable road material and cooperation be had with experiment stations, colleges, and universities, and with the men of enterprise who are now actively seeking such information and such assistance.

DIVISION OF PUBLICATIONS.

NUMBER AND COST OF PUBLICATIONS.

During the year 603 different publications were issued, aggregating 26,420 pages of printed matter, and the total number of copies was 7,075,975, greatly exceeding the work of any previous year. Of this number, 176 were Farmers' Bulletins, of which 2,437,000 copies were printed and distributed. The cost of printing these publications was $91,966.59, and of blanks, blank books, etc., $36,624.93, making the amount expended for this purpose $128,591.52. There was paid for artists and illustrations, labor and materials in connection with the distribution of documents, and for artists' supplies, $29,836.55, making the total expenditures under the supervision of the Division of Publications, exclusive of the amount appropriated for statutory salaries, $158,428.07.

In this connection, it may be said that the care and prudence which have characterized the management of the Department printing are strikingly manifested by a comparison of the number and cost of the publications since the period when the Division was first established. In 1891, the first year when the Division was fairly organized, there was expended for actual printing 59.8 per cent of the total appropriation for that year, while 40.2 per cent was expended for editing, illustrating, and distributing, whereas in 1899 of the total appropriation for printing only 27.1 per cent was absorbed for editing, illustrating, and distributing, leaving 72.9 per cent available for actual printing. Thus, in 1891, when the total appropriation was $87,600, the number of copies of publications printed was 2,348,447, while in 1899, with total appropriations of $185,260, the number of copies of all publications printed was 7,075,975, showing a proportionate excess of at least 2,000,000 copies in the actual output of printed matter in 1899 over 1891.

FARMERS' BULLETINS.

Of the total number of copies of Farmers' Bulletins printed (2,437,000), Senators, Representatives, and Delegates in Congress took 1,101,985—considerably less than last year and the year previous. Under the law, when Senators, Representatives, and Delegates do not avail themselves of the entire number of Farmers' Bulletins allotted to them, the same revert to the Department for miscellaneous distribution or for satisfying further Congressional orders. I am therefore able, for the current year, to increase the quota of Farmers' Bulletins allotted to Members of Congress from 4,000 to 5,000 copies. During the year 22 new Farmers' Bulletins were issued and 154 of those heretofore published were reprinted. Most of the bulletins of this series are of permanent value, and are therefore suitable for continuous distribution. It is my intention to still further increase this series by adding to it bulletins upon such subjects as the people seem to require information, and to give the same the widest possible distribution. The total number of Farmers' Bulletins issued since the series was inaugurated up to the close of the fiscal year ending June 30, 1899, was just 100, and the total number of copies printed was 11,270,500, of which Senators, Representatives, and Delegates in Congress have received and distributed 6,851,752.

MISCELLANEOUS PUBLICATIONS.

Of publications other than Farmers' Bulletins, 427 were prepared in the various Bureaus, Divisions, and Offices of the Department. As usual, these bulletins, many of them scientific or technical in character, have been distributed as judiciously as possible, the effort being to place them in the hands of those only to whom they will be of special interest and value, and to prevent waste or duplication. I regret that under the law the editions of some of the most valuable of these bulletins are restricted to 1,000 copies, so that the important information they contain can not be given the wide dissemination it should receive. It is earnestly hoped that this unwise restriction may be speedily removed, so that there may be no obstacle to the distribution of publications for which an urgent demand exists. It is interesting to note in this connection that during the year the Superintendent of Documents sold 18,750 copies of the publications of this Department, which had been turned over to him under the law, constituting 70 per cent of all the public documents disposed of by him during that time, thus indicating that there is a considerable number of persons to whom the small price affixed by the Public Printer is no obstacle to obtaining publications in which they are interested.

THE YEARBOOK FOR 1899.

The Yearbook for 1899 is now in course of preparation and is modeled in accordance with the plan suggested in my last report. It will contain a résumé of the achievements in the United States in every branch of science related to agriculture during the nineteenth century, and it is hoped that Congress will see the propriety of ordering an extra number, say 20,000, for distribution at the Paris Exposition in 1900. In connection with our agricultural exhibit, the distribution of special-bound copies of this publication would serve the useful purpose of acquainting foreign countries with the achievements in agriculture in the United States.

AN EVIDENCE OF THE DEPARTMENT'S USEFULNESS.

This steady and rapid growth in the publication work is a most gratifying indication of the success of the Department in fulfilling that section of the organic law creating it which makes it an essential part of its duty to diffuse information among the people on subjects relating to agriculture. Brief, popular pamphlets continue to afford the most acceptable means of widely disseminating the results of the Department's investigations, while the scientific and technical publications, still considered as standard works of reference and authority by scientists both in this country and abroad, are accorded their deserved prominence in libraries and institutions of learning. The people have a right to look to this Department as the highest authority on every subject connected with agriculture, and the number of publications issued which are designed to supply the information requested, as well as the very wide distribution given to them, is a most satisfactory indication that the Department is occupying the place intended for it in the machinery of the General Government.

THE LIBRARY.

GROWTH OF THE LIBRARY.

Additions to the Library during the past year have numbered about 4,000 volumes, including some very rare works and scarce sets of periodicals. The periodical list of the Library is growing very fast, owing to the efforts made to increase our exchange lists with publishing scientists and the officials of various countries. There are currently received by the Library at the present time nearly 2,500 periodical publications, more than 1,800 being obtained by way of exchange and gift. The care of this mass of literature is becoming a more and more serious problem in the limited room at the disposal of the Library.

CATALOGUES.

The card catalogue during the four and a half years since its inception has grown enormously. There are now more than 50,000 cards in the catalogue, covering, in author and subject entries, more than two-thirds of the books in the Library. The publication of a catalogue of books on forestry has shown that the collection on this subject is extremely full, having undoubtedly more than three times the extent of any other similar collection in this country. Catalogues of the books on botany and chemistry are well advanced and will probably be published before the end of next year. There is also in progress a complete author and subject catalogue of the publications of the Department of Agriculture since 1839, with such analytical entries as will bring out the subjects of separate papers in publications like the Yearbook and the Farmers' Bulletins.

DEMAND FOR THE PUBLICATIONS OF THE DEPARTMENT.

The demand for the publications of the Department is increasing at home and abroad very rapidly. They are attracting great attention among the learned men of foreign countries. We receive in exchange for them a large proportion of the valuable agricultural publications of all countries, and every attempt is made by correspondence to increase the material obtained in this way.

DIVISION OF ACCOUNTS AND DISBURSEMENTS.

For the fiscal year ended June 30, 1899, Congress appropriated for the Department of Agriculture $2,829,702. By the same act $720,000 was provided for the 48 agricultural experiment stations. The total expenditures for the year amounted to $2,797,173.49. The unexpended balances were covered into the Treasury.

SECTION OF FOREIGN MARKETS.

INQUIRIES REGARDING FOREIGN TRADE.

Our heavy foreign trade within late years has attracted much attention, both at home and abroad. Numerous inquiries have been received regarding the commercial opportunities offered by the former Spanish possessions. No authority has been given to this Department to get exact information regarding trade facilities in Puerto Rico, Cuba, and the Philippine Islands. The Section of Foreign Markets, has, however, collated and published everything available regarding the trade of those islands. Frequent inquiry comes regarding trade in China and Russia, which seem to offer great commercial possibilities in the immediate future. There is a dearth of reliable information regarding both these countries.

REPORT ON THE TRADE OF THE PHILIPPINE ISLANDS.

The report by this Section on the trade of the Philippine Islands required an unusual amount of research. It was found that the statistics from Spanish sources were meager and gave a very inadequate idea of the commerce that belonged to these islands. The Section has also printed a report dealing with the agricultural resources of the islands, especially plant products, to meet the great demand for information on this subject. The report contained a general description of the most important Philippine cereals, vegetables, roots, fibers, dye plants, etc., supplemented by statistics of production, price, and exportation.

AGRICULTURAL EXPORTS AND IMPORTS.

The record for 1898 shows that our agricultural exports were decidedly the largest in the history of the country. Their total value reached $858,507,942. Among the exports that showed the largest gains were wheat and wheat flour, corn, oats, rye, bacon, lard, hams, cotton-seed oil, and oil cake. It was found that there was a falling off in the agricultural imports, the total value being $314,291,769, which was $86,579,672 less than the year previous. The decline in agricultural imports for 1898 amounted to 22 per cent. Sugar and wool were the principal factors that marked this falling off.

STUDY OF DANISH IMPORTS FROM THE UNITED STATES.

A study of Danish imports from the United States shows that that country was importing in considerable quantities some of the articles that enter most extensively into its export trade—butter and bacon, for example. The Danes, having established a profitable market for butter and bacon abroad, sell their own and buy from us. It is not well established, however, that they do not import American farm products for reexport under local names. We know that American bacon is heavily imported into Ireland and sold in England as Irish bacon. We have also information from agents abroad that the thrifty people of that country (Ireland) import well-bred American horses and sell them to the English, in many cases, as Irish hunters.

American wheat flour is competing in Denmark with the home product. During the fiscal year 1898 our shipments of this article to Denmark amounted to 61,019 barrels, more than 20,000 barrels in excess of the largest shipments previously sent. The Danish bakers find that the American flour is as good as the best Hungarian, although less expensive, and it is being generally substituted for the latter. The milling industry of Denmark is declining. Every indication points to an increase in the amount of flour imported from the United States.

The American farmer is furnishing cow feed to the Danes. They imported 16,874,943 bushels of indian corn in 1898. This, in addition to the more nitrogenous mill feeds imported, enables the Danish farmers to supply the British markets with some thirty-three million dollars' worth of dairy products every year. The growth of the dairy industry in the United States indicates that before many years the American farmer will feed his cow feed at home and sell the product of his skill in foreign markets. The Danes bought 55,958,939 pounds of oil cake from the United States in 1897, and in 1898 they bought

155,121,048 pounds. The American farmer can not afford to export the nitrogenous by-products of the mills, as the soil that grows them is regularly reduced by taking them from the farm.

In this connection, it may be interesting to state that butter made in Denmark from these American imports is peculiarly well adapted to the markets of tropical countries. The butter has a higher melting point than butter made from the wider carbonaceous ration generally used in the United States. We raise linseed in the United States to get the oil with which to make paint for our buildings, but have not learned that the nitrogenous by-product is of the first importance in feeding live stock, especially the dairy cow. We are also shipping considerable quantities of bran, and the trade is growing in these nitrogenous exports.

The Danish farmer is enabled to furnish the markets with the finest possible product, and at the same time maintain the fertility of his acres. The Danes are reclaiming waste lands through the use of fertilizers resulting from the purchase of our nitrogenous by-products. We are reducing our lands to sterility by selling these products. It is the duty of this Department to assist the farmers of the United States to find markets for all their surplus products. It is also our duty to warn them of the consequences of exporting stock feed to foreign countries. The Danes have developed a heavy export trade in some of the products of the farm, and the secret of their success lies in the great pains they take to cater to the particular requirements of the foreign consumer and the care they exercise to maintain the uniform high standard of their products.

Not only is every precaution taken to prevent the exportation of inferior or damaged articles, but sufficient attention is always devoted to the packing and methods of shipment to insure arrival in good condition of the articles exported. We exercise no supervision over the shipments of American dairy products. The foreign buyer can depend upon the character of the consignments received from the Danes, but unscrupulous traders in the United States devote their utmost energies to imitations of our best dairy products. Some years ago we had an excellent market in Great Britain for our cheese, whereupon a spurious article was exported that destroyed the good name of American cheese. This is being done now with regard to American butter.

Copenhagen is the natural distributing center for the trade of the Baltic Sea, and it has established a free port for the transshipment of merchandise billed to other destinations. The amount of American merchandise distributed through the Baltic region is increasing very rapidly. During the fiscal year 1898 our direct shipments to these Scandinavian countries amounted in value to more than $25,000,000. Although agricultural products form a large part of this item and show a material gain for the past decade, the principal increase has occurred in our shipments of manufactured wares, such as machinery, tools, utensils, etc.

Ten years ago the annual value of the exports of manufactured articles from the United States to the Baltic countries did not exceed $3,000,000. It now amounts to $10,000,000. Meanwhile the annual value of our agricultural exports to the same region has risen from less than $10,000,000 at the beginning of the decade to about $15,000,000 at its close. As long as the United States produces the cheapest cow feed in the world for export, the market for agricultural products will grow in the Baltic countries. Our best opportunity in this region, however, lies in the development of a wider demand for our manufactures, of which the prospect is excellent. Transshipment at Copenhagen for other Baltic ports is a blunder on our part. American ships should take goods to their destination under the American flag in all parts of the world.

WORK OF THE SECTION IN FURNISHING INFORMATION.

One of the most useful features of the work performed by the Section of Foreign Markets is the furnishing of information to American citizens all over the country regarding these lines of industry. These inquiries are very extensive. Pamphlets have been prepared, and others will be, covering the information in most general demand, and at a time when the products of our fields and factories are so much beyond the requirements of home markets, the work of this Section is peculiarly valuable.

BUREAU OF ANIMAL INDUSTRY.

NUMBER OF ANIMAL INSPECTIONS AND COST.

The report of the chief of the Bureau of Animal Industry for the last year shows that the work carried on by the Bureau is increasing rapidly from year to year, and is becoming more and more an important factor in the economy of animal production and in the exportation of animal products. Meat inspection was conducted during the last year at 138 abattoirs in forty-one cities. The total number of antemortem inspections of animals was 53,223,176, of which 34,405,973 were for official abattoirs and 18,817,203 for abattoirs in other cities and for miscellaneous buyers. The number rejected upon this examination was 156,539. The growth of this feature of the work is shown by the fact that in 1892 the total antemortem inspections for official abattoirs was only 3,809,459. The total number of postmortem inspections was 34,163,155. The cost of this inspection was $465,709.23. The cost per head on antemortem inspection was 0.88 cent; in 1892 the cost per head was 4.75 cents, and only once was it less (0.8 cent).

The number of hog carcasses examined microscopically was 2,227,740.

Of this number, 2,160,230 were free from all appearance of trichinæ and 25,913 contained only trichinæ-like bodies, while 41,597, or 1.87 per cent, contained living trichinæ. The exports of this pork to countries requiring inspection amounted to 108,928,195 pounds, while only 70,046 pounds went to countries not requiring inspection. The cost of this work was $198,355.14, or 8.9 cents for each carcass, and 0.182 cent for each pound exported.

There were inspected for export 436,595 American and 67,688 Canadian animals. The number of inspections of vessels for carrying export animals was 852. Of the cattle exported to Great Britain, the losses were but 0.31 per cent; of sheep, 1.54 per cent; of horses, 1.11 per cent.

The expense of inspection of animals for export, the supervision of the movement of Southern cattle, and the inspection of animals imported from Mexico amounted to $107,023.31. It is estimated that the cost per head of inspecting cattle and sheep for export averaged 13 cents. During the quarantine season of 1898 there were unloaded at stock yards north of the infected area 911,455 quarantine cattle, and there were inspected in the noninfected area of Texas 236,369 cattle for shipment into other States for grazing. The imports from Mexico requiring inspection at the boundary line were 79,908 cattle, 1,254 sheep, 64 hogs, and 121 goats. The imports from Canada, not subject to quarantine, were 90,468 cattle, 172,985 sheep, and 1,769 horses. Some of these were for breeding, but the large majority were for feeding purposes. The total number of animals received at the ports of import was 2,463.

All of this work was done to prevent the spread of disease among the animals of the United States, to protect consumers from diseased meats, to secure the arrival of our animal products in foreign markets in good condition, and to maintain the reputation of those products at home and abroad.

LOSS FROM BLACKLEG.

According to the latest report, it is estimated that the annual loss of cattle from the disease known as blackleg, or symptomatic anthrax, in the districts principally affected has ranged from 5 to 35 per cent. The Bureau of Animal Industry has been for some time distributing a vaccine for the prevention of this disease, and this, it is estimated, has reduced the loss to 0.54 per cent among the animals treated. As it is known that a large percentage of this loss was due to careless operators, it is believed that with more care in the use of the vaccine future investigations will show a still further reduction. Vaccine is still being sent out, and during the fiscal year 545,289 doses were distributed. The indications are that the contagion gradually dies out where systematic inoculations are practiced, and it was with the hope of eradicating the disease from many sections that the preparation of vaccine was undertaken.

TEXAS-FEVER INVESTIGATIONS.

The experiments of the Bureau demonstrated that Northern cattle might be made immune from Texas fever by inoculating them with the blood of immune animals. This has recently been adopted and practiced with most satisfactory results by some of the experiment stations. The practical application of this discovery is of great importance both to the breeders of improved stock in the more Northern States and to the cattle raisers of the infected district, as it permits the improvement of Southern herds without the discouraging losses that have heretofore always occurred.

Experiments have been continued with a view of obtaining a mixture in which cattle from the Texas fever districts may be dipped for the destruction of the ticks which spread the disease, and which at the same time will not injure the cattle. This effort has not been entirely successful, but the progress of the work heretofore leads to the hope that such a mixture may be found. The difficulty in finding such a mixture is plain to those who know how tenacious of life is the tick which is the carrier of this disease.

Investigations in Puerto Rico show that the cattle tick is prevalent there, but the ticks which were brought from there and placed on cattle in the United States failed to produce Texas fever. Whether this result was accidental or whether these ticks are without infectious properties is a question of great importance. If further investigations show that the Puerto Rican tick is free from the Pyrosoma, the true contagion of the disease, and that the cattle of Puerto Rico are susceptible, the introduction of a single animal bearing the Pyrosoma might convert these comparatively harmless parasites into the most deadly scourges of the bovine race. This subject will receive further attention during the current year.

TREATMENT FOR HOG CHOLERA.

The preparation of serum for treating hog cholera and swine plague has been on a very much larger scale than last year, and the results are exceedingly satisfactory. The diseased herds in four counties of Iowa have been under treatment, the results showing a saving of from 75 to 80 per cent of the animals injected, though the final reports are not all received at this writing. It is evident, however, that this method of treatment is far in advance of any other heretofore tried.

SHEEP SCAB.

For many years the parasitic disease of sheep popularly called scab has been quite prevalent, especially among the flocks of some of the

Western States and Territories. Diseased sheep have been shipped from one State to another in violation of the law, and the stock yards and stock cars have been almost continually infected. The result of this condition has been that sheep could not be purchased for feeding purposes in any of the markets of the country without danger of bringing to the farm with them the contagion of this disease.

Sheep scab has been one of the greatest evils which the sheep industry has had to contend with. Not only does it always damage and often destroy the fleece, but it reduces the strength and condition of the affected animals so much that they fall an easy prey to internal parasites or succumb to unfavorable conditions of food and surroundings. Congress has specifically referred to this disease in the appropriation act as one of the diseases which the Department is authorized to control by sanitary regulations.

The first step taken by the Department looking to the limitation and control of this disease was the issuance of a circular letter notifying transportation companies and shippers of the existence of the contagion, and pointing out the prohibition of shipment and the penalty provided by law. Subsequent to this an order was issued that diseased sheep discovered by the inspectors in the channels of interstate commerce should be detained and dipped before going on to destination; also, that sheep purchased in infected yards for feeding should be dipped before they were allowed to go to farms. The effect of these orders was to protect the purchasers of store sheep and to lessen the number of diseased animals sent to market. It was found, however, that some of the dips used by the stock yards, companies, and owners of sheep were not efficacious under the conditions which obtain in this service, and that others were so severe or poisonous as to be dangerous. An order has, consequently, been issued specifying the kinds of dips which would be recognized and the manner in which these should be prepared and applied.

The effect of these measures has been extremely satisfactory, and the number of diseased shipments received at the principal stock yards have been very materially decreased. This has been accomplished without putting the shippers of healthy sheep to any inconvenience or expense unless the animals were going to farms from infected stock yards. The inconvenience of detention and the expense of dipping have had an excellent effect in lessening the number of diseased sheep sent to market, and has led to active efforts everywhere to cure them on the farm or ranch before shipping. The indications are at this writing that it will soon be possible to make the stock cars, the central stock yards, and other channels of interstate commerce safe and free from infection, in which case store sheep could be purchased in the markets without danger of infection, and only diseased sheep would come under the restrictions.

EXPERIMENTAL EXPORTS OF DAIRY PRODUCTS.

The experimental exports of dairy products made during the last two years and now in progress under special provision of law have produced marked results. But these are not satisfactory in all respects and the reputation gained needs to be protected by authority from Congress for some system of export inspection. The new markets opening for our dairy products require a guaranty of the purity and quality of butter and cheese sent from the United States, such as is given by other Governments, and especially Canada.

Not long ago this country supplied and practically controlled the cheese market of Great Britain. In some years we sent to England nearly 150,000,000 pounds, or two-thirds of our entire cheese product. But as no system of export inspection existed to guard the established reputation, unscrupulous merchants exported great quantities of inferior, adulterated, and counterfeit cheese, until the reputation of States cheese was destroyed in England, and that market lost to us. Canada, on the other hand, adopted a system of government control, was enabled to guarantee all cheese exported as pure and of standard quality, and thus secured, and still holds, the desirable British cheese trade which this country lost. We have recovered a little, but only a little, of the lost ground. The best cheese now exported from this country goes through Montreal, seeking the same avenues and the good company of Canadian cheese, finding a market virtually as a part of that product.

The same unfortunate result seems likely to follow the efforts to export fine creamery butter to Great Britain unless measures are promptly taken to avoid it. An active demand has arisen for this butter especially in the northern counties of England, supplied from Manchester, largely through the experimental efforts of this Department. During the summer of 1899 an exceptional scarcity of European butter caused very high prices, and British merchants sent large orders to New York. In the month of August our butter exports were six times as great as for the same month a year ago. This new and profitable demand for fine creamery butter had scarcely begun, however, before large quantities of an inferior article and also of imitation creamery, "process," or renovated butter, began to appear among the exports.

This article, which is a more dangerous and damaging counterfeit of fresh creamery butter than straight oleomargarine, was sent to New York by the carload for export. In at least one instance parties had renovated butter put up in the West, in the style of package adopted by this Department in its recent export trials to England, and this went abroad labeled "Finest American creamery butter." The effect of this upon future butter trade with Great Britain will probably be like that which followed the export of so much unidentified filled cheese. Already English merchants, who have been trying to introduce States creamery butter among their customers, have written to this Department complaining of the deception practiced upon them.

Out of six large lots of butter received by one firm at Manchester from the United States, all represented as "extra creamery" goods, five were rejected as being far inferior to the quality represented—apparently only poor imitations. Meanwhile Canada is forging ahead, with government supervision and guaranty to assist, and securing for its creamery butter a firm hold in the British markets. The lack of some protection by Government certification of exports from this country is already causing butter shipments by way of Canada, as in the case of cheese, previously mentioned. British merchants state that some of the best States creamery butter they have lately seen (as shown by makers' marks) has been among lots received from Canada.

I recommend, as a simple and effective remedy for these growing evils and obstacles in our export trade, that the existing system of Government inspection and certification of meats and meat products for export be extended by law so as to include butter, cheese, and condensed milk and cream. With slight modifications the organized force and regulations which now give protection and standing to our meat exports may be made to cover the new work proposed. The services of an inspector who is an expert in butter and cheese would be necessary for parts of the year at three or four exporting points; but until these exports increase New York would be the only place at which such an inspector would have to be continuously employed.

If such inspection and certification is authorized by Congress, the pure and unadulterated dairy products of the United States that are of a quality entitling them to official indorsement can be given a position in foreign markets which they can not otherwise secure, and which will enable them to compete successfully with like products from any other country.

This inspection of dairy products for export has been indorsed by nearly all the national and State dairy organizations in this country and has met with decided approval by commercial bodies and by individual exporters wherever it has been duly considered.

DIVISION OF STATISTICS.

INVESTIGATIONS DURING THE YEAR.

The condition of the agricultural industry, as indicated by the area of land devoted to the cultivation of the principal products of the soil; the actual volume of production and the value of particular crops, both on the farm and in the principal markets; the cost of production per acre and per unit of quantity and the cost of transportation; the number and value of farm animals and the losses annually resulting from disease and exposure; the volume, condition, and prospects, according to the season of the year, of such of the crops of foreign countries as compete with those of the United States in the world's markets, have constituted the field of investigation in which this Division has been engaged during the past year.

STATISTICAL REPORT.

Of the regular periodical reports of the Division there has been printed a total of 1,621,700 copies. These reports cover that general work of the Division which is continuous in its operation and which has constituted for a generation or more the only source of information available to the farmer that has been comprehensive, prompt, and unbiased.

THE CROP-REPORTING SYSTEM.

No change of essential or far-reaching importance has been made during the year in the methods of collecting agricultural statistics, but there is a marked improvement in all the different agencies employed, the monthly reports being more complete, giving evidence of greater care in their preparation, and generally displaying a more intelligent conception of the requirements of the Department on the part of its correspondents.

At the end of the fiscal year the organization included 41 salaried State statistical agents, with 8,730 correspondents, upon whose reports their monthly statements were mainly based; 2,627 county correspondents, with 7,881 aids and 36,426 township correspondents reporting each for his own immediate neighborhood. From this large body of persons—selected with great care, not only as to their geographic distribution, but also as to their qualifications for the performance of the duties required of them—reports have been received monthly, and at the close of the calendar year a select body of farmers, numbering about 90,000, reported upon the crops of their own individual farms. The Department is indebted to numerous transportation companies for monthly returns of cotton carried over their respective lines, information which has been of the greatest value in the making up of its final returns on the production of cotton.

No important change in the crop-reporting system will be recommended until the approaching federal census shall have furnished the Department with a new and definite statistical basis as to the distribution of crop areas. The Department's system is based, in the main, upon a periodic comparison of the acreage devoted to particular crops with that so used in the preceding year, and it is consequently not only impossible to make any increase, during the closing years of an intercensal period, in the number of products reported upon, but it is difficult, even as regards those which are reported upon, to keep to introduce States creamery butter among their customers, have written to this Department complaining of the deception practiced upon them.

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No change of essential or far-reaching importance has been made during the year in the methods of collecting agricultural statistics, but there is a marked improvement in all the different agencies employed, the monthly reports being more complete, giving evidence of greater care in their preparation, and generally displaying a more intelligent conception of the requirements of the Department on the part of its correspondents.

At the end of the fiscal year the organization included 41 salaried State statistical agents, with 8,730 correspondents, upon whose reports their monthly statements were mainly based; 2,627 county correspondents, with 7,881 aids and 36,426 township correspondents reporting each for his own immediate neighborhood. From this large body of persons—selected with great care, not only as to their geographic distribution, but also as to their qualifications for the performance of the duties required of them—reports have been received monthly, and at the close of the calendar year a select body of farmers, numbering about 90,000, reported upon the crops of their own individual farms. The Department is indebted to numerous transportation companies for monthly returns of cotton carried over their respective lines, information which has been of the greatest value in the making up of its final returns on the production of cotton.

No important change in the crop-reporting system will be recommended until the approaching federal census shall have furnished the Department with a new and definite statistical basis as to the distribution of crop areas. The Department's system is based, in the main, upon a periodic comparison of the acreage devoted to particular crops with that so used in the preceding year, and it is consequently not only impossible to make any increase, during the closing years of an intercensal period, in the number of products reported upon, but it is difficult, even as regards those which are reported upon, to keep exact step with a fluctuating acreage and a constantly varying production when the cumulative effect of even a small annual error in a report based on percentages may reach large proportions.

A PUBLICATION FOR CROP CORRESPONDENTS.

Much of the improvement so gratifyingly in evidence in the reports of correspondents is doubtless attributable to the issue of a new monthly publication known as "The Crop Reporter," designed for the exclusive use of the Department's crop correspondents. The necessity of compressing into very small space the instructions printed upon the monthly reports, the marked localization of the area of production in the case of not a few of the crops reported upon, and the general lack of uniformity in the agricultural methods and conditions obtaining in the different sections of the country have alike suggested the employment of some agency by which correspondents could be more fully instructed as to their duties and the instructions given them be better adapted to their various needs.

Such an agency has been found in the new publication, which has been received with many expressions of satisfaction by correspondents in every part of the country. By anticipating their needs, interesting them in their work, making intelligible to them the relation which, as individual correspondents, they bear to one of the most important branches of the work of the Department, and putting into their possession, without trespassing upon the province of the agricultural journals, a great variety of information calculated to make them better judges of agricultural conditions, and consequently more valuable correspondents to the Department, "The Crop Reporter" has been the means of greatly improving the crop-reporting service, while incidentally reducing the enormous correspondence of the Division by nearly one-half.

SEED DISTRIBUTION.

COST OF DISTRIBUTION AND FAVORABLE REPORTS RECEIVED.

An appropriation of $130,000 was made by Congress for the purchase and distribution of valuable seeds, etc., during the year 1899. Of this sum, there was expended for the purchase of seeds for distribution through Members of Congress $70,978.36. For rare and valuable foreign seeds distributed by the Section of Seed and Plant Introduction, under the Division of Botany, $20,300.92 was expended; for the purchase of sugar-beet seed distributed to experiment stations and individuals, $2,366; for seeds and bulbs distributed to Members of Congress through the Division of Gardens and Grounds, $3,400, and for seeds distributed for special investigation by individuals in the several States, $3,000. There was paid for salaries of employees connected with the seed distribution $25,912.98, and for miscellaneous supplies in connection with the work, $221.85. There are some outstanding vouchers for freights, etc., not yet adjusted.

The contractor was required to provide a building within the City of Washington in which to pack the seeds, and samples were tested by the Division of Botany for purity and germination. The high quality of the seed now being sent out by the Department is scarcely equaled by any of the distributing agencies of the United States. Of 979 letters received regarding the seed distributed, 972 report favorably upon the quality.

AIM OF THE DEPARTMENT IN THE DISTRIBUTION OF SEED.

The original intention of Congress in providing for the distribution of seed undoubtedly was to do for the producers a class of work they could not do for themselves—to search the various localities of the Old World for seeds and plants, and distribute them in the United States to the several regions where they would be most likely to succeed. The Department at present is endeavoring to bring back the practice, as much as possible, to the original intention of Congress. Quite a large percentage of the $130,000 appropriated is now spent in finding, purchasing, importing, and distributing rare seeds and plants.

The Department is in receipt of letters from seedsmen throughout the country urging the discontinuance of this work, and there is an uneducated sentiment here and there cooperating with the seedsmen along this line, which prompts ill-informed individuals to concur with these representations. I am well satisfied that the introduction and distribution during the last two years of seeds and plants rare or not found at all in the United States has been worth more money to the people of the country than all the expenditures of Congress for seed distribution to date. To the extent to which the distribution by the Department competes with the sales of seedsmen and others distributing precisely the same kinds of seed, with no experimental feature and no intelligent direction regarding the use of the seeds beyond that which is provided by dealers, the practice is questionable. But the furnishing to the people of the United States of sugar-beet seed of the most approved quality, for experimentation, to ascertain where beets can be grown sweet enough to produce our own sugar, is justifiable; the introduction of drought and rust-resisting grains from foreign countries, which are urgently needed by people in the United States who are losing heavily from drought and rust, is justifiable; the rehabilitation of the Western ranges that have been destroyed and in many cases reduced to desert conditions by injudicious grazing, is justifiable; the encouragement of tea growing in the States along the Gulf of Mexico, where labor is as plenty and as idle as anywhere in the world, is justifiable; the inquiry into the several plants that produce rubber, the gathering of the seed of these plants, their germination and preparation for setting out in such localities in the new island possessions of the United States Government as may be best suited for producing the $30,000,000 worth of rubber now purchased from foreign countries, is justifiable; the introduction of the date palm from Tripoli in Arizona, establishing a new industry in that region which may extend to other localities in the same latitude, is justifiable. The introduction of these and many other seeds and plants, entirely beyond the ability of private individuals to compass, in order that such seeds and plants may eventually enter the commercial class and be handled by seedsmen, is the aim of the Department of Agriculture in seed distribution at the present time.

SUGAR BEETS.

During the last three years extensive experimentation has been had in cooperation with most of the States of the Union to ascertain where sugar beets can be produced sufficiently sweet to justify extensive growing and manufacturing. It has been fairly well demonstrated that many States have soil and climate, fuel, water, and limestone admirably adapted for this industry. Thirty-two factories are now in operation and many more in contemplation. There is every indication that the United States will produce its own sugar within a few years. The rich valleys of the mountain and Pacific coast States find sugar making very profitable. It is being demonstrated that the rich cornfields of the Northern States are also admirably adapted to the growth of the sugar beet. This industry will eventually be more profitable where the by-product is fed to the dairy cow and other domestic animals. The Department publishes annually a report setting forth all the facts in relation to this industry and the latest developments of interest to producers.

THE MARKET FOR AMERICAN HORSES.

Within the last two years horses have greatly appreciated in value and exports have rapidly increased. The Department issues annually a revised report, giving horse raisers facts regarding exports, as well as the requirements and demands of foreign countries for horses for different purposes.

DOMESTIC TEA PRODUCTION.

EXPERIMENTS AT SUMMERVILLE, S. C.

An interesting experiment is being conducted at Summerville, S. C., in the production of tea. Three thousand six hundred pounds of dry tea were produced during the past season. Dr. Shepard, a gentleman of education and enterprise, who owns the garden, has overcome the difficulties arising along labor lines by building a schoolhouse for the education of the children of his colored neighbors, where they are taught free of expense, with the understanding that they shall pick his tea when required, at a reasonable rate of wages. This class of labor in the South is very plenty and very idle. The elementary education and habits of industry acquired must have a good effect from every standpoint from which the best interests of these people can be considered. If a new industry of this kind can be introduced into the Gulf States, which will save the people of the United States the many millions of dollars now sent abroad for the purchase of this commodity, and at the same time provide light work for the young people who are now entirely idle, there is a double incentive to make research to the utmost regarding the production of a commodity in such universal use.

INVESTIGATIONS TO BE CONDUCTED.

Congress at its last session appropriated $1,000 to enable the Department to conduct experimentation in tea growing. While the average rainfall at Summerville ranges between 50 and 60 inches, there are times when the rain does not fall for considerable periods. Experimentation is now being arranged for to ascertain whether by irrigation a more continuous growth can be maintained and more frequent picking of the leaves be had. Arrangements are also being made to experiment in the manufacture of green tea without the use of chemicals. The Department of Agriculture has a sufficient number of plants growing in pots to start experimental tea gardens in all the Gulf States from Florida to Texas, and including California. Efforts are being made to induce the experiment stations in those States to cooperate with the Department in conducting these experiments.

Experiments in South Carolina have shown that the production of 200 pounds of dry tea per acre is readily obtainable under favorable conditions, with a probability of double or perhaps treble that amount when the plants have arrived at full bearing. It is desirable to ascertain the limit of productiveness under all the varying conditions of surface, soil, and seed varieties. It is gratifying to note that the yield per acre has steadily advanced, in spite of all hindrances, from 50 to 150 pounds per annum per acre for the whole of the older tea gardens at Summerville within the past few years. The best varieties from all the countries of the Orient are being experimented with, and efforts will be made to add promising new varieties, both by importation and by hybridization. Experimentation of this nature is beyond the capacity of men of moderate means, and I am of opinion that it is entirely justifiable that Congress, through the Department of Agriculture, should assist in demonstrating the probability of raising tea in the United States, for home consumption at least.

It will be necessary as the work progresses to employ professional tea tasters of wide experience to indicate the value of the several varieties being experimented with. A higher valuation per pound may offset a lesser production. Experimentation in shading from the direct rays of the sun is very encouraging. The leaf thus produced was tender, very lustrous, and made a very delicate tea. The means of manufacturing must of necessity be increased, and the testing of new machinery as regards cheapness of work and thoroughness of execution provided for. It is desirable to study carefully the composition of tea made from the same bushes at different times during the picking season, to analyze the product in this country of gardens raised on soil from widely separated sources, and to test the effect on tea of different sorts of manure. This is a large and expensive kind of experimentation, requiring special chemical apparatus and unusual nicety and skill.

LEASING THE PUBLIC LANDS.

CONDITION OF THE RANGES.

I have looked carefully into the condition of the ranges in most of the States west of the Missouri River. The Department of Agriculture has been conducting experiments in most of these States with native and imported grasses through the experiment stations, private individuals, and sometimes directly under the management of its own officers. Injudicious grazing has greatly impaired the capacity of the ranges to produce meats. Careful inquiry shows that in many cases the ranges do not support more than half the meat-bearing animals they did ten years ago. The ranges have been overstocked, the grasses have been eaten bare and pulled out by the roots, and where formerly nutritious grass supported a large number of animals, there is now left nothing but a desert of drifting sand.

The principal reason for this condition of the ranges undoubtedly is that no single individual has an interest in any one part of the public domain. The object of the flock master is to secure all the grass possible, irrespective of the effect it may have on the future condition of the pasture. Thousands of sheep that can not find grazing on the plains are being taken into the innermost recesses of the mountain systems.

LEASING AS A MEANS OF IMPROVEMENT.

It would seem wise to inaugurate a more sensible policy regarding these public grazing lands. They should be rented to individuals in sufficiently large areas and for a sufficiently long time to induce the lessee to give attention to their improvement. The title should remain in the United States, so that the homesteader might have an opportunity, under such conditions as would not interfere with the renting, to make settlement wherever practicable. The rents arising from these leases might very well be given to the States for such uses as they might deem wise, either for educational purposes or for irrigation work. A very considerable amount of money would come every year from these leases, with which the States could begin experimentation in the way of building dams and holding the water against a time of need. My main object in making this recommendation is that the lessee and the Department of Agriculture may enter into cooperative experimentation looking to the improvement of the grazing lands.

EFFORTS TO SECURE PLANTS FOR SEMIARID REGIONS.

There are millions of acres that can not be cultivated in any crops with which we are now familiar. The Department of Agriculture is searching the dry areas of the world for plants that may be successful in furnishing the materials of food to a greater extent than is now practicable on our semiarid regions. The introduction of sorghum, Kafir corn, dry-land alfalfa, the Russian brome grasses, etc., is enabling the farmers of the States west of the Missouri to extend cultivation over lands that did not succeed in corn, or oats, or clover.

ABANDONED FARMS.

My attention has been called to what is known as the abandoned farms of New England. A personal inspection of some of these farms shows that they are not abandoned on account of sterility of soil, but are in many cases capable of affording a good living to industrious farmers, and under more favorable auspices than are farms in some of our newer States, on account of nearness to market, educational institutions, and other desirable environments. The Agrostologist of the Department has visited several of these farms to ascertain in what way help can be given by the introduction of grasses suitable to their various conditions, and the Soil Physicist will study conditions on these farms and indicate which soils may be profitably cultivated and which should be devoted to forestry. The Forester will also visit these localities and determine what varieties of trees are most desirable. The Department will endeavor to have Farmers' Bulletins prepared along these several lines for distribution among the farmers of New England.

TROPICAL IMPORTS.

Our imports of tropical-plant products have a value of about \$200,000,000 a year. Nearly all of these could be produced in Puerto Rico, Hawaii, and the Philippines if the best use were made of the agricultural possibilities of these islands, and of American industry, ingenuity, and financial resources. Our tropical-plant imports are four times as great as the total exports of Hawaii, Puerto Rico, and the Philippines. For coffee and sugar we pay an amount exceeding by more than \$80,000,000 the agricultural and all other exports of these islands. Omitting sugar and tobacco, our tropical-plant imports still greatly exceed the total agricultural exports of these tropical dependencies. Our imports of oranges, lemons, and cocoanuts have about the same value as the sugar and tobacco exports of Puerto Rico, and could readily be produced on that island.

There are several staple agricultural imports of the United States other than oranges, lemons, and cocoanuts to which attention should especially be called as worthy of consideration for introduction into Puerto Rico, such as vanilla, our imports of which vary in value from $279,755 to $1,013,608 per year; gutta-percha and india rubber, about $30,000,000, and cacao, $5,000,000. The improvement and extension of coffee culture in Puerto Rico is well worth careful investigation and encouragement, since our total coffee imports in 1898 amounted to $65,067,631. There is every reason to believe that a portion of our banana imports, which during the year 1899 reached a value of $5,665,588, may to good advantage be grown in Puerto Rico.

INDIA RUBBER.

IMPORTANCE OF THE TRADE.

The india-rubber trade is of great importance to the United States and has shown a rapid increase during the last few years. For the fiscal year ended June 30, 1890, the total importations of crude rubber amounted to 33,842,374 pounds, valued at $14,854,512, while that of manufactured rubber was valued at $367,647. In the fiscal year 1898 the imports of crude rubber and gutta-percha amounted to 46,055,497 pounds, valued at $25,386,010, while that of manufactured articles and waste or scrap rubber was 9,488,327 pounds, worth $805,951. This shows not only a decided increase in the quantity imported, but also a rapid rise in price. In 1890 about two-thirds of the entire amount imported came from Brazil. In 1898 about three-fifths came from that country.

A recent United States consular report shows that the importations into England for 1898 amounted to 20,026 tons, about half of this being Brazilian. New fine Para rubber was quoted at New York from 66 to 69 cents per pound in 1893, 69 to 71 cents per pound in 1894, 73 to 77 cents in 1895, 74 to 88 cents in 1896, 80 to 87 cents in 1897, and 82 to 83 cents January 1, 1898. A single cargo of rubber, consisting of 1,167 tons, shipped from Para February 23, 1898, was valued at $2,210,000 in United States gold. The exports of rubber from Brazil in 1898 amounted to $38,400,000 gold.

COLLECTION AND TREATMENT AND SOURCES OF SUPPLY.

Rubber is derived from the milky sap of a number of trees and shrubs, all native to the tropical regions of South America and the Old World. There are many plants with milky sap which contain small quantities of rubber, but none are known which produce it in commercial quantities anywhere outside of the Tropics. The methods of collection and treatment of rubber are, in the main, very crude. There is a great deal of waste and considerable deterioration through improper methods of treatment in the field and in transit, and through impurities. The only successful experiments at cultivating rubber plants which have thus far been made were undertaken by the English Government in Ceylon, India, and some of the other tropical colonies. By following the most improved methods of cultivation and by giving the rubber plantations the same careful attention which is devoted to other crops, it appears possible to make this an exceedingly profitable investment.

The larger part of the Brazilian rubber is produced by the Para rubber tree, *Hevea brasiliensis*, which grows naturally in the deep shade of the swampy forests of the Amazon, where the air is fever-laden and the land is unsuited for human habitation. Experiments have been made with this tree in various of the British possessions in the East Indies, but without any marked degree of success, because the tree attains its full development only in the shade of dense tropical jungle lands and not in the solid plantations. Its successful handling appears to lie in the direction of a proper system of forest management. The Central American rubber tree, *Castilloa elastica*, grows only in the dense tropical forests from southern Mexico to northern South America, on rich, well-drained bottom lands along the rivers. This tree has been found to grow luxuriantly under cultivation, but in the experiments thus far tried it develops a bark much thicker than in its native state, and this has been found a decided drawback to the successful drawing of the sap.

The Ceara rubber tree, *Manihot glaziovii*, is a native of one of the driest portions of southern Brazil, where the mean temperature ranges from 77° to 86° F. There are now many plantations of it in India and Ceylon, and it is probable that this tree will be the first to produce an important addition to the natural supply of india rubber. There are fifty or more species of trees, vines, and shrubs which are a commercial source of india rubber and gutta-percha, and the list is annually increasing. Experiments should be tried in the cultivation of every one of them. Gutta-percha is derived almost entirely from the tree *Isonandra gutta*, a native of the islands of the Malayan Archipelago. The careless methods of the collectors have resulted in killing off most of the plants from which this substance is derived, so that a serious shortage has occurred during the last few years. The feasibility of cultivating this plant in the Philippines should be very carefully investigated.

TURKESTAN ALFALFA.

The unusually severe winter of 1898–99 killed off probably half of the alfalfa of western Kansas, Nebraska, Colorado, and Wyoming, and many fields in the central prairie States to the eastward were badly damaged, but the Turkestan alfalfa grown in the States mentioned was not affected. At the Wyoming experiment station a plat of Turkestan alfalfa was exposed for two weeks without injury to a daily temperature of —35° F., the lowest point reached being —45°. In California it was subjected without damage to a drought which seriously injured ordinary alfalfa. In view of the notable success of this plant in withstanding drought and cold, it has been decided to purchase a large amount of seed grown in America from our imported stock and to distribute it widely over the arid West until it has been thoroughly tested under all the different climatic and soil conditions existing in that region. From the results already secured, it is believed that this one introduction will add millions of dollars to the annual hay product of the United States.

INTRODUCTION OF IMPROVED RICE.

About fifteen years ago the enterprising farmers of southwestern Louisiana began to adapt modern machinery to use in their rice fields, and within a decade they had replaced the antique implements of the hand laborer by the gang plow, disk harrow, drill, and broadcast seeder; they had insured sufficient water by the construction of irrigation canals; and, finally, they had adapted the twine binder of Northern wheat fields to the cutting of rice. So far as methods were concerned, they had created a new system of rice culture which greatly reduced the cost of rice production. It was discovered, however, that sufficient attention had not been paid to the question of varieties. The Louisiana rice, when milled, gave a high percentage of broken grains, and much of it brought, therefore, only a second-class price.

To remedy this difficulty the Department of Agriculture undertook to secure a productive rice of high milling quality. This it has succeeded in doing by importing, after a careful search in Japan, a quantity of Kiushu rice. In yield this rice has proved a distinct success, and if, as is expected, it maintains in Louisiana the high milling average that it possessed in Japan, hundreds of thousands of dollars will be added to the yearly profits of Louisiana rice growers.

In this connection, it may be said that flattering reports have been received about many of the other introductions of the Department, and from time to time, when these reports are amply substantiated, due commendation of these crops will be made to the agricultural public.

NATIVE DRUGS.

The collection of native drug plants in the United States, considered from a purely financial standpoint, aside from medical and humanitarian aspects, involves the expenditure of millions of dollars annually. The commercial extermination of some of the most useful species is already threatened, and doubtless others would be found in the same condition were the facts known. The price of one native plant, ginseng, our exports of which average more than half a million dollars annually, has more than quadrupled in the past thirty years, so that its cultivation, as urged four years ago by this Department, has now become profitable. It is clear from this and many similar cases that the native drug industry is capable of either decline or improvement, according to the way in which we handle it.

The Pan-American Medical Congress has recently submitted to me a proposition to cooperate with this Department in a technical and statistical investigation and classification of our native drug plants. By accepting this proposal we shall secure, in a research of which we have long felt the need, the cordial assistance and support of an influential association of learned physicians; we shall encourage each of the other American nations, all of which are represented in the Pan-American Medical Congress, to proceed with a similar investigation of their own medical flora; we shall furnish a basis for the remunerative employment of much land and many people, and we shall stimulate the great and growing trade in drugs between the countries of North America and South America. I urge the appropriation of $10,000 to enable this Department to cooperate in this investigation.

HEMP.

Our imports of hemp fiber for the past five years have averaged in value $678,475 annually, coming chiefly from Italy and southern Russia. This hemp is worth about 7 cents per pound and is used principally in the manufacture of carpet warps. In addition, we import an unknown but doubtless large amount of manufactured hemp in the form of the cheaper grades of linen. The domestic product of hemp reported by the last census, at a valuation of 3 cents per pound, was worth $690,660 and was grown chiefly in Kentucky. This hemp is used principally in place of jute butts for cordage purposes. The Kentucky hemp producers grow a short plant in small areas with shallow plowing and little or no fertilizing. The crop is reaped and broken by hand, and the fiber is extracted by the process of dew retting. In addition to these heavy charges, an annual rental, averaging probably $10 per acre, is ordinarily paid for the land. There is a reasonable prospect of establishing an extensive hemp industry in the United States on new lines, involving the use of either a taller variety or two crops of the short variety, growing the crop on large areas of cheap land, plowing deep, putting on the necessary fertilizers, reaping and breaking by machinery, and using the process of water retting.

EGYPTIAN COTTON.

The importation of cotton from Egypt steadily increased from less than 200,000 pounds in 1884 to more than 43,000,000 pounds in 1896. Since the latter date, the direct importations from Egypt have fallen off slightly, but the prices have had an upward tendency, and the demand for this staple remains good at from 4 to 6 cents higher than the price of ordinary American upland cotton. Our annual import of cotton from Egypt for the past three years has averaged in value $3,738,338. The Egyptian cotton has a very fine silky fiber, generally shorter than that of sea island but longer than that of upland varieties. It is used in the manufacture of fine yarns for the finer qualities of hosiery and knit goods. It does not come into direct competition with our upland cotton, the fiber of which is too coarse for the finer yarns. Some attempts have been made to grow Egyptian cotton in this country, and in 1894 the Department imported and distributed a stock of Egyptian seeds. The experiments with these have shown promising results, but there is need of further trial to determine the exact conditions under which this cotton can be grown to best advantage. There is good ground for hope that with proper management the industry may become well established in the United States.

NEW LABORATORY BUILDINGS.

The Department of Agriculture is now conducting all of its laboratory work in rented buildings located outside of the Department grounds. These buildings are for the most part mere makeshifts, consisting of dwelling houses remodeled to permit laboratory work. Some of them are overcrowded and none are fireproof. There are five of these buildings which, with rent and other expenses, cost the Department about $10,000 a year. The work carried on by the laboratories is of the highest importance, including the investigations of the Bureau of Animal Industry, the Division of Chemistry, the Division of Vegetable Physiology and Pathology, the Division of Soils, and the Division of Botany. Much of the material now in use by these branches of the Department, as well as that being constantly accumulated by them, is of great value, and it would be impossible to replace it in case of loss by fire. It is absolutely necessary that better facilities be secured for this scientific work, either by the rent of additional buildings or by the erection of a Government building.

As best adapted to our necessities, plans have been prepared for suitable buildings to be erected upon the Department grounds. The plans show structures which are fireproof throughout, and which are arranged so that the several lines of work can be kept as distinct as may be required by their nature, and at the same time the buildings be heated, lighted, and ventilated from one central plant. The several laboratories are now occupying, approximately, 35,000 square feet of floor space, and the new buildings provide about 10 per cent increase over this to allow for future growth. Careful estimates show that the buildings as planned will cost, approximately, $200,000. I therefore earnestly recommend that this amount be appropriated, as it will not only be a saving of money to the Government, but will at the same time furnish facilities commensurate with the importance of the work

A PROPOSED ARBORETUM.

One of the needs of the Department is an arboretum in which can be brought together for study all the trees that will grow in the climate of Washington, D.C. The need of such an establishment was felt early in the history of the Capital, and was brought forward more than fifty years ago among the various plans proposed for the use of the Smithson bequest, which was finally devoted to the founding of the present Smithsonian Institution. In the report of the building committee of that institution for 1850 the following statement occurs:

> Mr. Downing, the well-known writer on rural architecture, at the request of the President, is now preparing a plan for converting the whole Mall, including the Smithsonian grounds, into an extended landscape garden, to be traversed in different directions by graveled walks and carriage drives and planted with specimens, properly labeled, of all the varieties of trees and shrubs which will flourish in this climate.

This admirable plan, apparently from lack of financial support from Congress, was never systematically prosecuted, and the plantings at first made were so neglected that the nurse trees crowded out and killed most of the valuable sorts, and even the nurse trees themselves are now being rapidly broken down and destroyed by storms, disease, and decay. When the grounds of the Department of Agriculture were laid out in 1868, Mr. William Saunders, then, as now, Horticulturist of the Department, established a small arboretum commensurate with the size of the grounds. An arboretum in this climate, however, requires an area of several hundred acres. The time has come when the economic needs of the Department and the education and pleasure of the people demand a rich collection of trees planted so as to secure the best effects of landscape art, furnishing complete material for the investigations of the Department of Agriculture, and so managed as to be a perennial means of botanical education. We are now engaged in introducing useful trees from all parts of the world, such as those producing fruits, dyes, nuts, oils, and tans, those useful for ornamental purposes, and especially those promising shade, shelter, and fuel in the arid region. At the present time we have no central place in which to plant and maintain a series of these trees for study and propagation. The importations must be sent out as fast as they are received, without an opportunity for our investigators to make any observations on their behavior under cultivation, and, in the case of small and valuable importations, subjecting the whole stock to the possibility of total loss. In view of these conditions, I wish to bring to the attention of Congress the importance of placing at the disposal of this Department an area of suitable size and situation for a comprehensive arboretum. In order to give a specific basis for consideration of this project, I suggest that the area known as the Mall be set aside for this purpose.

AGRICULTURAL EDUCATION.

NECESSITY OF AGRICULTURAL TEACHING IN INSTITUTIONS OF LEARNING.

The great prosperity of the country at the present time has resulted, among other things, in a largely increased attendance upon our universities, colleges, and other institutions of learning. When we consider that half the people of the United States are occupied in producing from the soil directly; that about three-fourths of our exports to foreign countries come from the soil, and that the $600,000,000 balance of trade coming to the United States during each of the last two fiscal years have been, to a great extent, the price of farm products, it is somewhat remarkable that so very little attention is given to the education of half the people of the nation and their preparation for their future life work.

The beautiful valleys of the mountain and Pacific-coast States are being injured to a considerable extent by the injudicious use of irrigating waters. The pasture lands of the public domain west of the Missouri River are being rapidly destroyed by injudicious grazing. The wheat-growing area of the country, where crops are grown continuously, are refusing to yield as they did when first brought under cultivation; and from the Dakotas to the Pacific we find systems of fallowing in operation and crops of wheat being taken once in two years, indicating the rapid destruction of the plant food in the soil.

SCIENTIFIC TRAINING IN THE DEPARTMENT.

The people cry aloud to this Department for help. We have gone repeatedly but in vain to the Civil Service Commission and had them advertise throughout the country for soil physicists in order that we might cooperate with the people regarding the deterioration of their soils. All the older sections of the United States have injured their soils by injudicious management. A knowledge of plants—their life history, the diseases to which they are subject, their relations to the soil, the climate, and food necessary to their best development—is so scarce among us that plant physiologists and pathologists can not be found by advertising for them.

Animal husbandry is very little understood, and in most of the educational institutions of the country sufficient instruction is not being given to have it better understood, yet from this source we make our most profitable sales to foreign countries. The Biological Survey and other Divisions have also to train the men to do their work. When the Department requires the assistance of men educated along these lines it is necessary to educate them in its own scientific Divisions, under the direction of its own scientists. When it has trained such men until they become expert and stand at the head of their specialties in the United States (and in many cases in the world), then wealthy institutions take them away by offering higher salaries, interfering with the work of the Department, along the lines mentioned, which is so necessary to the producers of the United States.

REGISTER OF GRADUATES OF LAND-GRANT COLLEGES.

To meet some of these difficulties and avoid in future their frequent recurrence, I have arranged with the Civil Service Commission to make a register of the graduates of the land-grant colleges of the United States (those endowed by Congress to educate the young farmers of the country). From this registration the scientific Divisions of the Department select young men who will assist the Division scientists in their work, and have opportunities for post-graduate study and for better preparing themselves along the lines of applied science, whereby the producer is helped by the scholar. We pay these young men no more than we pay a laborer, and much of the work they will perform in the Divisions could be performed by skilled laborers.

Slight inquiry into education along the lines of agricultural science will show that there is no university in the land where the graduate of an agricultural college who has been studying along the lines indicated can take post-graduate work. The scientific Divisions of the Department of Agriculture come nearer furnishing the necessary facilities than can be found elsewhere. If two or three young men come to each of our scientific Divisions and study along the lines of the application of science to production in the field, the stable, and the farm factory, the Department will in a few years have a force from which it can not only fill vacancies when wealthy institutions take away trained men, but be able to supply the agricultural colleges, experiment stations, and other scientific institutions in the land with men of superior scientific attainments in these branches.

EFFORTS OF THE DEPARTMENT TO MEET THE DEMANDS FOR HELP.

By this new departure the Department is merely arranging to meet the imperative demands of the producers of the country for help to solve the problems that are beyond their education and their means. The Congress of the United States, in providing for the endowment of agricultural colleges and experiment stations, did more for the agriculture of the country than has been done by governmental agency for the people of any other nation. Congress could not endow these institutions with teachers trained in the applied sciences relating to the farm, but Congress has built up the Department of Agriculture and encouraged the development of the foremost scientists known in their several specialties. The step we have taken toward bringing the brightest students of the agricultural colleges to prosecute their studies under the supervision of scientists in this Department is one step necessary to complete the educational system.

Something no doubt remains to be done at the other end of the educational line. The education of the young farmer in the district and high schools should be such as to help him toward the agricultural college. The other educational institutions of the country have done their work well, but so abundantly that the college graduate upon leaving college is not sure of employment that will give the salary of a brakeman on the railroad. Only a very few of those who upon leaving college must earn their livelihood through their literary education are sure of incomes equal to that of a locomotive engineer. The great unexplored field for the educator is along agricultural lines. Half the people of the United States are interested in it. The prosperity of our country as a nation among nations depends upon it.

I hope to have the approval of Congress in this effort to provide for the higher education of the graduates of the agricultural colleges by appropriations sufficiently considerate to justify the very moderate expense that will be entailed.

AGRICULTURAL TEACHING IN THE COMMON SCHOOLS.

In my last Annual Report, I referred to the growing interest in elementary instruction in the sciences that relate to agriculture, and mentioned the special appropriation of $25,000 made by the State of New York to be used in aiding the introduction of nature teaching into the common schools and the carrying on of simple agricultural experiments in different parts of the State under the supervision of the college of agriculture of Cornell University. Encouraging progress has been made during the year in this movement. The work at Cornell has been materially extended, and colleges in other States are affording opportunities for teachers in the common schools to receive such special instruction as will fit them to give elementary courses in nature study. In Missouri a recently enacted law calls for instruction in agriculture and horticulture in the common schools, and during the past summer a considerable number of Missouri school superintendents and teachers spent some time in attending lectures and formulating elementary courses of instruction in these studies.

CONCLUSION.

The Department, through its Bureaus, Divisions, and Offices, is getting into more immediate contact with all classes of producers throughout the country. More extensive cooperation is being entered into between the Department and the experiment stations of the several States. Especial attention is being given to the reclamation of soils that have been reduced in fertility by injudicious management. Production from the soil in all parts of the United States is being diversified by importations from foreign countries. The scientist and the cultivator are working together for greater national prosperity through more economic production. The farmers of the country are having their knowledge increased through the publications of the Department and the experiment stations, and the future tillers of the soil are being better educated in the agricultural colleges as teachers are developed who more thoroughly understand the application of science to practical agriculture. The field of operations for the future activity of the farmer is from the Arctic Circle to the Equator. New problems, requiring scientific investigation and entirely beyond the ability of localities or private individuals to solve, are presented from both extremes. The especial attention of the Department in the future will be given to the production, under United States jurisdiction, of products of the soil that now come from foreign countries, keeping steadily in view the object for which the Department was organized—the help of the producer who is struggling with nature.

Respectfully submitted.

JAMES WILSON,
Secretary.

WASHINGTON, D. C., *November 21, 1899.*

WORK OF THE METEOROLOGIST FOR THE BENEFIT OF AGRICULTURE, COMMERCE, AND NAVIGATION.

By F. H. Bigelow,

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INTRODUCTION.

A consideration of the development of meteorological science in the United States, especially in its practical application to agriculture, commerce, and navigation, involves mainly a review of the United States Weather Bureau and its work. Not only, as will be shown, is the study of meteorology largely confined in this country to its professors and other employees, but the application of the results obtained to the service of the farmer, the shipper, and the navigator, is and has been for years exclusively the province of the Bureau. Necessarily, therefore, a large part of the present paper must be devoted to a history of the Weather Bureau and an account of its workings.

THE ORGANIC LAWS ESTABLISHING THE WEATHER SERVICE.

The Weather Bureau of the United States has reached its present development under three organic laws. The joint resolution approved February 9, 1870, is as follows:

> *Be it resolved by the Senate and House of Representatives of the United States of America in Congress assembled*, That the Secretary of War be, and he hereby is, authorized and required to provide for taking meteorological observations at the military stations in the interior of the continent and at other points in the States and Territories of the United States, and for giving notice on the northern lakes and on the seacoast, by magnetic telegraph and marine signals, of the approach and force of storms.

In compliance with the appropriation bill of 1871, reports relative to the stages of water in the rivers were added to the above. The appropriation bill approved June 10, 1872, provided:

> For expenses of storm signals announcing the probable approach and force of storms throughout the United States, for the benefit of commerce and agriculture; and that the Secretary of War be, and hereby is, authorized and required to provide, in the system of observations and reports in charge of the Chief Signal Officer for such stations, reports and signals as may be found necessary for the benefit of agriculture and commercial interests.

In the act transferring the meteorological work of the Signal Office to the Weather Bureau of the Department of Agriculture, approved October 1, 1890, the duties of the service are thus summarized:

> The chief of the Weather Bureau shall have charge of forecasting the weather; the issue of storm warnings; the display of weather and flood signals for the benefit of agriculture, commerce, and navigation; the gauging and reporting of rivers;

the maintenance and operation of seacoast telegraph lines and the collection and transmission of marine intelligence for the benefit of commerce and navigation; the reporting of temperature and rainfall conditions for the cotton interests; the display of frost and cold-wave signals; the distribution of meteorological information in the interest of agriculture and commerce, and the taking of such meteorological observations as may be necessary to establish and record the climatic conditions of the United States, or as are essential for the proper execution of the foregoing duties.

THE THREE EPOCHS OF METEOROLOGICAL SERVICE.

The acts of Congress indicate that the meteorological service of the United States has passed through three distinct epochs, each of which has been natural in the practical development of this branch of science. The laws are in fact but the crystallized expression of the outcome of years of experience on the part of those interested in meteorology. Thus, the laws of 1871 and 1872 mark the end of a long agitation, the purpose of which was to persuade Congress that forecasts of the weather were practicable in the United States and that an organized systematic effort to give the public due warning of the approach of storms was worth a trial. The organization of this service was intrusted to the Signal Service of the War Department. At first the service was for the benefit of navigation on the seacoast and on the Great Lakes, but it was soon extended so as to include the interior districts and the great rivers of the central valleys.

The experience incident upon the gradual extension of the service soon showed that it would be necessary to include the regions adjacent to the United States in order to secure the most efficient forecasts of the weather, especially the Dominion of Canada, along our northern border, for the cyclones; the West Indies, to the south and southeast, for the hurricanes, and also Mexico and even Alaska for other local effects. The benefits of the weather service were readily appreciated by nearly every industry and every department of our complex civilization. Climate and crop conditions were demanded for the farmer, and observations and warnings for the public and for railroad and water carriers. Hence, it soon became necessary to enlarge the scope of the service so as to include agriculture and commerce as well as navigation, and to extend the sphere of the meteorologist to cover the study not only of the dynamics and motions of the atmosphere, but of climatology (the prevailing temperature and rainfall), together with their effects upon human life. This great enlargement of the original idea regarding the scope of the work gradually produced an environment which became less suited to the duties inherent in the purely military service that had so successfully fostered this very growth through twenty years, till at length it was concluded that a more strictly scientific bureau could better carry on the work. Accordingly, the second epoch came to an end on July 1, 1891, when the Signal Service of the War Department was relieved of its meteorological duties and the Weather Bureau of the Department of Agriculture was organized and charged with the future of meteorology in the United States.

In the latter administrative department of the Government the civilian and scientific methods predominate, though it must be said that the spirit of subordination inherited from the Army discipline still continues, and tends to make the organization of the Weather Bureau more efficient and homogeneous than it otherwise could be. A detailed review of the incidents connected with these changes in the service, both on the practical and on the theoretical sides, involves such a multitude of facts as to be quite incompatible with any brevity, if treated fully; hence, only a summary description of the service can be attempted here.

PRELIMINARY HISTORICAL SKETCH OF METEOROLOGY.

AMERICAN CONTRIBUTORS TO METEOROLOGY PRIOR TO 1870.

During the eighteenth century but little progress was made in detecting any sort of regular lawful sequence in the apparently erratic phenomena known as the weather. Franklin had perceived that storms moved northeastward from Philadelphia toward New England, which view was the result of his observations and private correspondence regarding the exact time when the maximum severity of storms was felt at different places. Thomas Jefferson, at Monticello, and James Madison, at Williamsburg, in Virginia, had taken some simultaneous observations in the years 1772–1777, and certain conclusions were drawn from them. The belief gradually took shape among students of the day, both in America and in Europe, that storms had a progressive movement and a whirling motion about the center. Lavoisier and Borda, in France, proposed to establish stations over a large territory and examine the simultaneous records in order to detect the laws of storms. Mitchell, in America, Capper, in India, Langford for the West Indies, and Brandes and Dove, in Europe, had contributed certain notions on the subject, some holding that storms are whirls in the atmosphere, though generally the view was expressed that they are straight-line gales. Charts of various kinds were constructed by different individuals, and the publication of these at length placed students in a position to begin the slow advance from mere hypothetical conjectures regarding the motions of the air to the definite scientific knowledge of the laws which we possess to-day. It is quite remarkable to note the extent to which American students have been pioneers in these meteorological researches, their views having been confirmed or elaborated rather than originally suggested by Europeans in their studies.

During the nineteenth century the observations of atmospheric phenomena have been enormously multiplied all over the world, and a correct scientific classification of them around fundamental laws has proceeded steadily, if not very rapidly. In 1831 Redfield published his first essay, which contained these important generalizations: Storms and hurricanes are great revolving whirlwinds which turn from right to left and have a northeastward, progressive movement; the winds increase in violence toward the center, where a calm usually exists; storms are gyrating portions of the atmosphere in which they are carried along, and the low barometric pressure at the center is due to the centrifugal force. In 1843 the same author ascribed the great velocity of the wind at the center of tornadoes to the law that the product of the velocity at any point multiplied by its distance from the center is constant. In 1846 he described the warm southerly winds on the easterly side of storms and the cold northerly winds on the westerly side, and thus nearly apprehended the cause of cold waves. He seems to have been fully aware that the winds do not move exactly in circles about the center, but rather approach it in spirals, and he stated that his instructions to the engraver were to make the wind lines spiral or involute in shape on his charts, but that, for ease in drawing, circles were substituted, which gave an erroneous impression regarding the theory to his readers. He stated distinctly, in 1846, that these lines made an angle of about 48° with the tangent to the circle. Espy, who was at one time appointed meteorologist to the National Government, was the first to study and point out clearly some of the temperature processes which are going on in the atmosphere. He applied the laws of thermo-dynamics in 1841, at about the time when this subject first took shape in theoretical physics, and showed that an ascending mass of air expands its volume and cools its vapor contents down to saturation, thus causing rainfall; that a descending mass warms by compression, clears the air of clouds, and causes it to appear to be dry; he proved that in the condensation of aqueous vapor to water the production of latent heat retards the rate of cooling with the ascent, and showed that the daily heating of the lower strata by the sun's rays produces a general ascending buoyancy during the early portions of the day, thus developing the cumulus and cumulo-nimbus clouds,[1] which dissipate in the evening as the strata settle back toward the ground; he attributed the rainy belt in the Tropics to an ascending movement and the clear space at the eye of a hurricane to a descending current of air; he also attempted to show that the cause of storms consisted in the local buoyant ascent of heated air, which produced a radial indraft below in the lower strata; but he failed to see that this reasoning could not account for the prevailing low pressures which permanently surround the cold polar regions.

The Espy theory of the cause of storms, namely, the convectional

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[1] By "cumulus" and "cumulo-nimbus" is meant the massive white clouds which form chiefly in the afternoons, often producing thunderstorms.

indraft in a radial direction, and the Redfield view that storms are essentially whirls in circles about a center with low pressure at that place due to centrifugal motion, contain elements in apparent contradiction to each other, and a long controversy ensued over the merits of these rival views, which is hardly yet completely settled in the minds of many students of meteorology. In 1843 Tracy published an article which added a new force in the construction of storms, namely, the right-hand deflecting component of motion in the Northern Hemisphere, which depends upon the rotation of the earth and is proportional to the velocity of motion and the sine of the latitude. Unfortunately, this was not noticed at the time, and it had no influence upon the controversy, though it is really decisive against Espy's theory of the radial direction of motion.

The labors of these intelligent students were rapidly bringing order out of chaos in meteorology. Such physical work was supplemented by the statistical results which were being compiled in various places. Coffin, in 1853, published his "Winds of the Northern Hemisphere." After his death, appeared his "Winds of the globe," edited by his son and the Russian meteorologist Woeikoff. He described the right-hand rotation of cyclones in the Northern Hemisphere and the left-hand rotation in the Southern. He considered storms to be eddies in the general currents of the atmosphere, and claimed that both Redfield and Espy had elements of truth in their theories, which must be mutually combined to produce a correct view of the subject. Loomis, of Yale College, also was engaged in the compilation of statistics and the construction of maps through his long active career as a meteorologist, and he added many important facts to our scientific knowledge, though no essential part in the theoretical development seems to be associated with his name. It was during the years 1850 to 1860, however, that the greatest advance was made in a systematic analysis of meteorological phenomena and that the reduction of the entire subject to definite mathematical expressions first took place. Prof. William Ferrel, of the Signal Service, has the honor of thus having first contributed an analytical description of the motions of the air, and therefore of having done most to establish meteorology upon a scientific basis. His work is so well known to students that it is not necessary to describe or comment upon it in this place. He was by nature a profound mathematician and an accomplished astronomical computer, and while some of his discussions are cumbersome, it must be remembered that he had not the advantage in his active years of advanced modern mathematics, which will surely find one of its most important applications in the study of the motions of the atmosphere.

Ferrel did especially good work in his treatment of the general motions of the air, but he is not now regarded as having been so successful in his handling of the local cyclones and hurricanes. His discussion of tornadoes was also ably presented, and can be improved at this time only in certain details. Regarding the cause and structure of local cyclones, Ferrel himself was never quite satisfied with his own conception. He saw distinctly the value of Espy's convectional buoyancy, of Redfield's gyratory rotation, and of Coffin's subordination of the local eddies to the general circulation of the air, and it is not too much to say that, while he wavered in his theory, he inclined strongly to Coffin's point of view. He unfortunately forced the parallelism of the local to the general cyclone so far that a reaction has taken place against him in recent years by students who have had the advantage of the use of the best modern materials. This mistaken comparison of the local cyclone with the general cyclone has been an important factor in the rather slow progress characterizing the last twenty years. In the hands of Ferrel, supplemented by the important contributions of many distinguished Europeans, meteorology has already reached such a development as to require a high order of mathematical talent to make any important advances.

THE WEATHER MAP.

The above brief account of the development of the principles of theoretical meteorology in the United States previous to 1870, the date when the subject was taken up by the National Government, has been necessary in order to show that meteorology had already acquired a firm standing among students of the subject. Yet, it is quite improbable that the Government would have been authorized by Congress to undertake such functions as were at that time assigned to it unless there had been in connection with the improvement in the theory a corresponding advance on the practical side, which would be of direct usefulness to the public. This consisted in the possibility of making forecast warnings of the approach of storms, in order to justify the heavy expenses connected with the collection of the observations, and the dissemination by telegraph of the information contained in the study of the simultaneous records. About 1784 Lavoisier, the famous chemist, suggested that instruments be scattered over France, and declared that with their aid "it would not be impossible to publish each morning a journal of predictions which would be of great use to society," so that the dream of forecasting the weather is a century old. After the invention of the electric telegraph, Lavoisier's idea became practicable, and in 1842 Kreil renewed the plan of collecting daily simultaneous observations of the state of the atmosphere. During the next ten years this view was urged by various scientific men, Redfield (1846), Henry (1847), Ball (1848), Maury (1851), in many papers and addresses. Brandes, Piddington, Espy, Redfield, Henry, Loomis, and others had been compiling weather maps from reports, and were convinced that there was sufficient sequence in the weather conditions to forecast them if the reports could be collected promptly enough and from a suitable number of widely distributed stations. The agitation therefore took the form of urging some cooperative scheme which would make this possible.

In 1848 Glaisher, and in 1851 the Crystal Palace authorities, made some weather maps. In 1856 weather charts were displayed every day by the Smithsonian Institution, in Washington, D. C., under the direction of Professor Henry, wherein appropriate symbols indicated the state of the atmosphere over the United States, and this enlightened plan was continued till interrupted by the civil war in 1861. Leverrier, the great astronomer of France, in 1854 studied the European reports received concerning the weather. In 1855 he submitted a plan to the Emperor for a meteorological network over France. In 1856 he began to make maps, with a system of thirteen telegraph and eleven post stations. In 1857 he published an international bulletin. In 1858 it became a daily bulletin. In 1863 he first made predictions for ports. On September 11, 1863, he printed the weather map for the day, and it has not been discontinued since that time. It is thus seen that to France is due the credit of first issuing a permanent set of daily maps with forecasts. After the conclusion of the American civil war efforts were renewed to set on foot a plan of meteorological operations for the United States. While the great extent of its territory made this country a most favorable theater for such a project, there was necessarily connected with the undertaking a very considerable expense for telegraphic messages, so that a scheme of operations on a large scale was essential to its inauguration.

In 1868 Prof. Cleveland Abbe, the veteran meteorologist of the service in this country, while director of the Cincinnati observatory, secured the assistance of the Cincinnati Chamber of Commerce and the Western Union Telegraph Company, so that he was able to prepare and issue a daily bulletin, and afterward a map based upon thirty stations covering the region from the Atlantic coast to the Rocky Mountain slope. These maps gave the temperatures, cloudiness, rain, snow, and the direction of the wind, but no pressure or isothermal lines. During the years 1845 to 1865 Congress was being urged to give authority for storm and weather predictions, by Espy and Henry on behalf of the Smithsonian Institution, Maury on behalf of the Navy, General Reynolds on behalf of the Army Engineer Corps, Major Lachlan on behalf of the American Association for the Advancement of Science, and Commissioner Watts on behalf of the Department of Agriculture. In 1869 Gen. A. J. Myer presented to the Secretary of War a scheme of weather warnings suitable for execution by the Signal Corps. Prof. I. A. Lapham, of Milwaukee, Wis., sought to secure for the Great Lakes the benefit of weather forecasts by extending the service over that region, and solicited the cooperation of the Chicago Board of Trade. He drew up a petition to the Chicago Academy of Sciences, but one of its most clear-minded members, Hon. Halbert E. Paine, said, "This petition should go to Congress, and the weather predictions should be for the whole country and not for any small section thereof." The indorsement of the National Board of Trade was secured. Mr. Paine obtained the approval and support of the Secretary of War, and, happily, procured the passage of the joint resolution by Congress, already quoted, which was approved February 9, 1870. Thus, the service of forecasting weather conditions was formally authorized by the Government of the United States and intrusted to the Signal Corps of the War Department, of which Brig. Gen. Albert J. Myer was in command.

ADMINISTRATION OF THE WEATHER SERVICE.

The successive chiefs of the Weather Service, including the chiefs of the Weather Bureau since its transfer to the Department of Agriculture, with their respective terms of office, have been as follows:

Brig. Gen. A. J. Myer, February 9, 1870, to August 24, 1880.

Adjt. Gen. R. C. Drum (acting chief), August, 1880, to December, 1880.

Brig. Gen. W. B. Hazen, December, 1880, to December, 1886.

Brig. Gen. A. W. Greely, December, 1886, to July 1, 1891.

Prof. Mark W. Harrington, July 1, 1891, to July 1, 1895.

Prof. Willis L. Moore, July, 1895, to the present time.

FEATURES OF THE SEVERAL ADMINISTRATIONS.

The prominent features of the several administrations, briefly stated, are as follows:

General MYER organized the service with the material at his hand, namely, the observers and sergeants of the Army Signal Corps. He introduced nearly all the methods of operation still in use by the office, including synchronous observations, telegraph circuits, weather maps, bulletins, synopses and forecasts, signals and distribution of warnings as widely as possible, the publication of daily, weekly, monthly, and annual reports of regular work, special investigations, instructions to observers, and information to the public. He sought to have organized a separate, permanent corps of officials, specially devoted to this service, instead of depending upon the military assignments of a more or less temporary character, but he was unable to accomplish this important improvement in the organization. General Myer also succeeded in securing the cooperation of the European weather bureaus in entering upon a plan of international simultaneous observations, which were to cover the Northern Hemisphere as far as possible. These were begun in 1875 and continued through General Hazen's term of office, till in 1887 General Greely was obliged to discontinue them on account of the expense.

General DRUM's administration was so far of a temporary nature as to give no opportunity to impress new methods and results upon the service.

General HAZEN sought in every way to improve the service, which had been founded on really broad lines, and became convinced that the military corps ought to be supplemented by a corps of civilian assistants, who should be favorably known for scholarship in meteorology, and who were to be free to pursue such studies, in an uninterrupted manner, as the service demanded. A body of such civilians was appointed in 1881–1884 by General Hazen, and they have become an indispensable part of the organization of the service. General Hazen furthermore entered upon the international scheme for the exploration of the Arctic Zone by simultaneous meteorological and magnetic observations, which was executed in 1881–82.

General GREELY took up what was now a well-organized and fully-equipped service already fixed in the esteem of the public in this country, and carried it along the same lines. He made further efforts to secure from Congress an independent set of officials for the meteorological service of the Signal Corps, and finally succeeded in that purpose by procuring the act of Congress approved October 1, 1890, which not only made permanent the organization, but also provided for the absolute transfer of the meteorological work from the Signal Corps of the War Department to the Department of Agriculture. The same act provided for the assignment of Army officers to duty in the Weather Bureau, and this remained in force till the outbreak of the Spanish-American war, when the provision was revoked in May, 1898, so that now the service is not only organized as a permanent corps, but is composed wholly of civilians. During General Greely's administration the fruits of several years' observations of the weather conditions of the United States began to appear in a series of valuable compilations, giving the normal distributions of pressure, temperature, rainfall, and the climatological features of the country.

The transfer of the meteorological work from the War Department did not change its essential features in any important respect, but left it free to develop along the lines most suited to its purpose.

Professor HARRINGTON, in his administration, was occupied by a transfer of the officials who resigned from the Signal Corps, and who were generally reappointed in the Weather Bureau; by a reorganization of the divisions in the office; by a considerable extension of the activities of the service in the number of stations which were occupied, the number of volunteer observers engaged, and the publication of a greater number of maps, reports, and special investigations. A somewhat unfortunate though very natural change had already manifested itself before this time, and yet one which could not be readily counteracted, namely, the practical absorption of meteorological studies in the United States by the national service and the diminution of the number of independent students scattered over the country. The growth of meteorological records, which are necessarily deposited at the central office, gives the professors of the Weather Bureau so great an advantage over outsiders in accessibility of the materials for scientific research as to practically exclude them from serious competition along these lines. This is to be regretted, because an intelligent body of students associated with the universities of the United States would not only serve to spread the knowledge of the higher meteorology, but would form a body whose opinions as to the good of the service should be always important.

Professor MOORE has met the practical wants of the public by an increase in the facilities for distribution of forecasts, by improvements in the local daily weather map, in the unification of the form of the local publications in the different States, by several important scientific investigations, including the relations of the sun to the earth through magnetism, the exploration of the lower strata of the atmosphere by means of kite ascensions and the higher strata by cloud observations in cooperation with the international commission during 1896–97. Many reports of permanent value continue to be issued by the office, and these are usually of a very practical character, though sometimes necessarily technical.

METEOROLOGICAL REPORTS AND STORM WARNINGS.

On November 1, 1870, at 7.35 a. m., the first systematized synchronous meteorological reports ever taken in the United States were read from the instruments by the observer sergeants of the Signal Service at twenty-four stations and placed upon the telegraph wires for transmission.

On the same day the tabular bulletin reports were furnished to twenty-four cities. A copy of this bulletin is given here as an interesting record. The drawing of isobar lines is quite impracticable from the data, but an improvement was speedily effected in the determination of the heights of the stations and the reduction of the actual pressures to the sea level, as shown by the fact that early succeeding bulletins gave smooth isobars. An excessive amount of space seems to have been assigned to the record of the wind velocity in three different scales. Provision was also made in the form of the table for the twenty-four hour changes in pressure and temperature, and for the relative humidity.

Copy of the first daily bulletin published by the United States Signal Office from the observations taken November 1, 1870, 7.35 a. m.

Place of observation.	Height of barometer.	Temperature.	Direction of wind.	Velocity of wind per hour.	Pressure of wind per sq. foot.	Force of wind.	Amount of cloud.	State of weather.
	Inches.	*Degrees.*		*Miles.*	*Pounds.*		*Per cent.*	
Boston	29.65	44	W.	3	.04	Gentle		Fair.
Buffalo	29.38	40	W.	7	.24	Light		Clear.
Cheyenne	27.12	45	W.	13	.83	Brisk		Clear.
Chicago	30.03	40	SW.	14	.75	Brisk		Clear.
Cincinnati	29.52	40	SE.	5	.12	Light	1.4	Clear.

Copy of the first daily bulletin published by the United States Signal Office from the observations taken November 1, 1870, 7.35 a. m.—Continued.

Place of observation.	Height of barometer.	Temperature.	Direction of wind.	Velocity of wind per hour.	Pressure of wind per sq. foot.	Force of wind.	Amount of cloud.	State of weather.
	Inches.	*Degrees.*		*Miles.*	*Pounds.*		*Per cent.*	
Cleveland	30.09	35	SE.	12	.83	Brisk		Clear.
Detroit	29.84	37	S.	5	.12	Light		Clear.
Duluth	28.99	37	SW.	4	.07	Light		
Key West	29.98	75	E.	4	.07	Gentle	4.4	Cloudy.
Lake City, Fla	30.05	62	0	0	0	Calm	1.4	Clear.
Milwaukee	30.07	42	W.	12	.83	Brisk		Clear.
Nashville	30.08	51	N.	2	.02	Gentle	1.2	Fair.
New Orleans	30.08	64	NE.	3	.04	Gentle	1.4	Fair.
New York	30.12	45	0	0	0	Calm		Clear.
Omaha	29.32	36	S.	4	.07	Gentle		Clear.
Oswego	29.94	44	W.	20	1.96	Very brisk		Fair.
Pittsburg	29.32	38	S.	3	.04	Gentle	1.4	Fair.
Rochester	30.03	40	W.	7	.24	Light	3.4	Fair.
St. Louis	29.91	45	SE.	7	.24	Light		Clear.
St. Paul	29.50	38	E.	1	.01	Very light		Clear.
Toledo	30.00	38	S.	2	.02	Gentle		Clear.
Washington	30.03	45	W.	1	.01	Light	1.4	Fair.

The first storm warning was telegraphed and bulletined along the Lakes on November 8, 1870. The issue of "Synopsis and probabilities," as they were styled, was commenced on February 19, 1871, and were made thrice daily after that date, the forecast being intended to cover only the twenty-four hours then next ensuing. Signal stations for cautionary warnings of storms were soon established along the Atlantic and Gulf coasts, and the first of such signals was displayed on Tuesday, October 26, 1871, at 7 p. m., at the port of Oswego, N. Y. Till the middle of 1872, the work of forecasting devolved upon the civilian assistant, and after that time was shared between him and officers detailed from the Army.

The growth of scientific work under General Hazen called for the services of specially trained scientists, and a number of civilian professors were appointed, but they all, with two exceptions, resigned in a few years; the transfer of the service to the Department of Agriculture and the opening of the Chicago and the Pacific centers for forecasts called for new men.

INSTRUCTION IN METEOROLOGY.

The first task devolving upon General Myer, in the organization of the service, was that of instructing a sufficient number of officers and sergeants as forecasters and observers, the definition of the duties in general meteorology, and in the proper transaction of the business connected with this new branch of the service. At Fort Whipple, now Fort Myer, Arlington, Va., there existed a school of instruction for officers of the Army and Navy, and the work of teaching a corps of meteorologists was added to its formal functions. During the first year seventy-three sergeants were instructed in the "Manual of signals," the "Practice of electrical telegraphy," Loomis's "Meteorology," "The Smithsonian instructions," and "Instructions to observer sergeants." Among the earliest papers published by the office were a practical treatise on meteorological phenomena, adapted to the use of observers, and instructions as to the details of office duties. Such writings have been kept prominently before the office ever since, and they have gradually covered every conceivable phase of the subject likely to be of value to the officials themselves or to the public. In 1872 there was established the so-called study room, under the charge of Professor Abbe, where scientific and practical questions were taken up for discussion, and this did good work in educating several men, who have since become well known in science, till it was officially abolished in 1886. Since that time the scientific problems have been assigned by the chief of the Bureau to the several professors, or else to boards especially appointed to report on definite propositions.

In the year 1882, by direction of General Hazen, the school of instruction at Fort Myer assumed a decidedly collegiate aspect in the extent and strength of the instruction offered. Courses of lectures were delivered by Professor Abbe on instruments, published later in 1887; by Professor Upton on practical astronomy; by Professor Hazen on meteorology; by Professor Waldo on elementary mathematics and thermo-dynamics. Other lectures on more general topics were delivered by Lieutenants Story, Dunwoody, and Birkheimer. This very commendable attempt to provide a much higher grade of education for meteorologists lasted until 1886, when the school at Fort Myer was discontinued. The demand for higher scientific instruction has been met to a very limited extent by the colleges and universities of the United States, and yet, as a distinct subject, meteorology has been taught in only a meager fashion up to the present time. This state of affairs is accounted for to a considerable extent by the fact that entrance upon a career as a meteorologist is almost entirely limited to the Government service, together with the circumstance that most of the routine work of the office, making the observations and distributing the forecasts, is of an elementary kind, and does not demand the knowledge of any large amount of mathematics or physics. The few professorships open to young men are so slowly attained as to discourage ambition in this direction. In 1892 and the following years the entire service was classified and became subject to the civil-service rules, so that examinations are now the rule for admittance to all grades. Under Professor Moore's administration progress is being made in prescribing requirements for entering the Government weather service and for promotions within it up to the highest grade, so that the educational side of the Weather Bureau is likely to assume gradually a definite and permanent character.

MEANS OF INSTRUCTION AND INFORMATION FOR THE PUBLIC.

Besides the persistent efforts which in one form or another have always been made to instruct the officials of the service in their duties as observers and in their scientific understanding of the problems of meteorology, a much more extensive and difficult task has been carried on simultaneously in the endeavor to teach the public to appreciate and appropriate the results of this systematic research into the laws controlling the weather. In spite of discouraging results attending the attempt to propagate much exact knowledge of this complicated science to a large population, the evidence preponderates that the work of the Government has already been of an enormous value to the whole country from an educational point of view. The inevitable failures attending the attempt to forecast weather conditions for periods of from twenty-four to forty-eight hours in so unstable a medium as the ever-changing atmosphere, filled as it is with long currents of different temperatures, large and small vortices, the sensitive physical processes giving rise to clouds and precipitation, must be admitted as an unavoidable part of the imperfections of this practical work. These errors were formerly used by the press and by critics generally as a ground for complaint against the service, but now it is notable how greatly improved has become the tone of criticism, which recognizes that the successes far outweigh the failures in forecasting. While there has not been any important advance in the amount of instruction given by the universities in the higher theoretical meteorology of late years, yet it should be observed that meteorology is extending rapidly throughout the common schools of the country as a required branch of instruction for every child, and it can be inferred that this process of beginning at the bottom will culminate in producing occasionally an individual who shall attain strength and success in studies embracing the highest reaches of science pertaining to the physics of the atmosphere. These changes have certainly resulted from the persistent propaganda of publications emanating from the Weather Bureau during the past thirty years.

THE ANNUAL REPORTS.

Among the most important publications of the service must be placed the Annual Reports of the chief of the Weather Bureau, which now comprise a most creditable array of volumes, filled with interesting and valuable information regarding the administration of the work and the latest results of scientific investigations. Therein one may find an account of the gradual growth of the service; a description of all the severe storms experienced since 1870, whether cyclones, hurricanes, or tornadoes, together with marvelous incidents in the history of the latter destructive agents; statistics of the wreckage of vessels on the Lakes and on the seaboard, showing a remarkable lowering of the percentages of wrecks in consequence of the obedience of navigators to the storm warnings; descriptions of the growing dependence of the railroads and other public carriers upon the information regarding heavy snowstorms, cold waves, and floods, which endanger all perishable products during transportation; data of the gradual improvement on the part of small farmers and great agriculturists in the care of their stuffs in consequence of the frost warnings and the increased knowledge of the effect of seasons and climate upon the crops; also facts showing the almost complete reliance of the cotton, rice, corn, wheat, and raisin industries upon the information regarding normal or abnormal temperatures and rainfall. There will also be found in these reports a description of the instrumental equipment of the meteorological stations, with the gradual evolution of self-registering apparatus of all kinds by means of electrical attachments, including barometers, thermometers; humidity, sunshine and cloud recorders; anemometers and vanes for the force and direction of the wind; self-measuring rain gauges, and kite and cloud-height apparatus of various kinds. Many of the self-registering pieces of apparatus display the greatest mechanical ingenuity in the devices employed, and their resulting records agree so closely with direct observations on the standard instruments as to be perfectly acceptable within the limits of accuracy required in current observations. (For kite and cloud-motion apparatus, see Pls. I and II.)

The practicability of such a service of course depends upon the telegraph for its efficiency in promptly collecting the observations taken simultaneously, on the Atlantic and Pacific coasts, on the Lakes and the Gulf of Mexico, and through the Rocky Mountain region and the central valleys. The magnificent result of receiving at Washington, D. C., and at all the larger cities of the country at the same time the complete records from one hundred and fifty stations within an hour after the observations are made is testimony to the skill and experience of the electricians of the Weather Bureau and the telegraph companies. This result depends upon special arrangements which have been slowly brought to perfection. The first of these arrangements is the cooperation of the telegraph lines, by which special wires are devoted to the Government service during certain hours of the day, when the weather messages take precedence of all private dispatches; in 1870 there were six telegraph companies concerned in transmitting weather messages, but these have all been merged into one; in 1871 there was some controversy as to the financial terms of the telegraph service, but it was settled by the fixing of rates through the Postmaster-General, and later Congress vested in the Secretary of Agriculture the power to make contracts with the telegraph companies; also to prescribe the precedence of all Government messages. The second arrangement consists in the establishment of certain telegraph circuits, including groups of cities in an extensive territory, so regulated that the same message is recorded simultaneously at all the

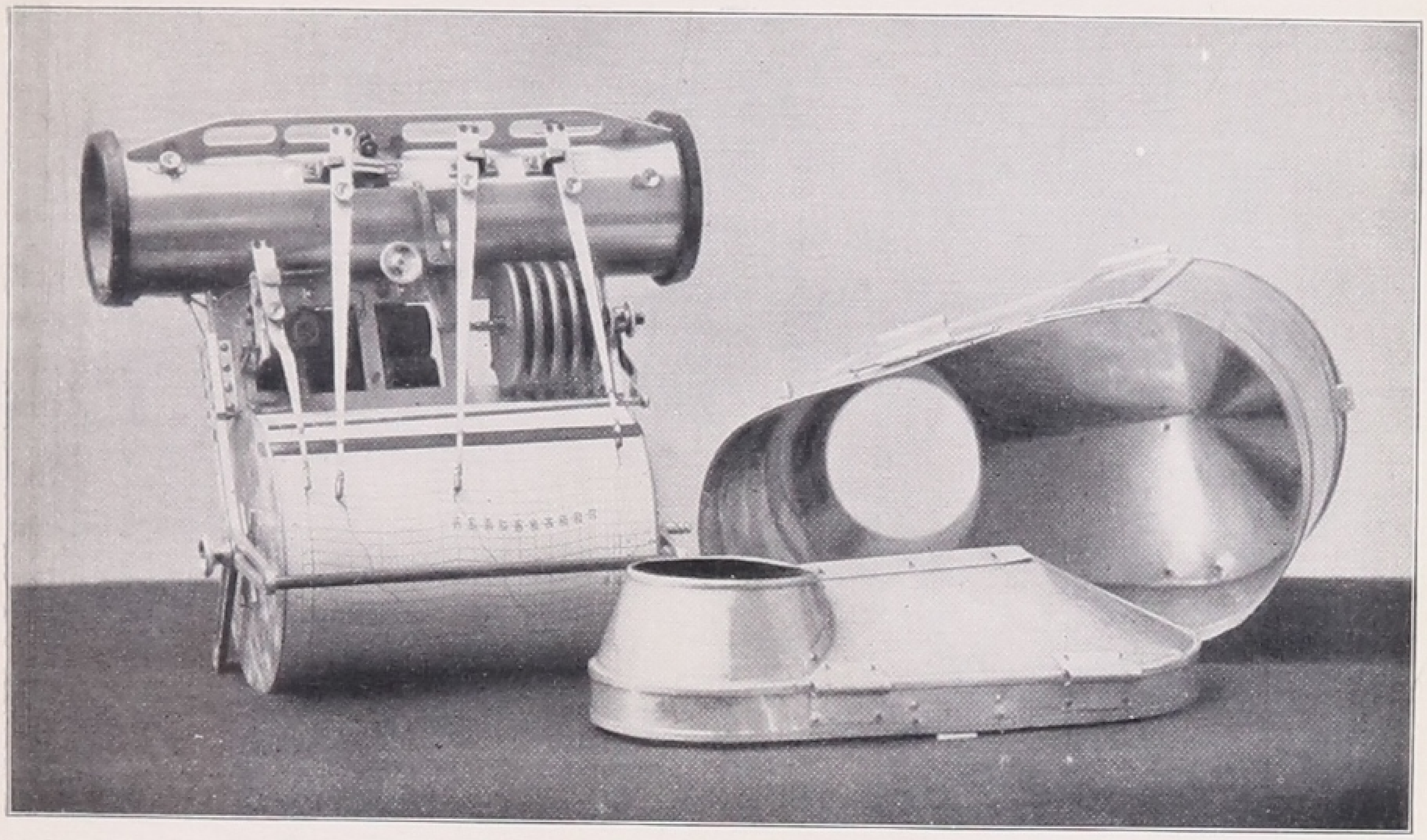

FIG. 1.—THE MARVIN METEOROGRAPH.

[Self-registering instrument to record the pressure, temperature, humidity, and wind velocity of the air. Very light in construction; adapted to kite ascensions where the minimum of weight is required for lofty flights. Used in the explorations of the lower atmosphere in 1898.]

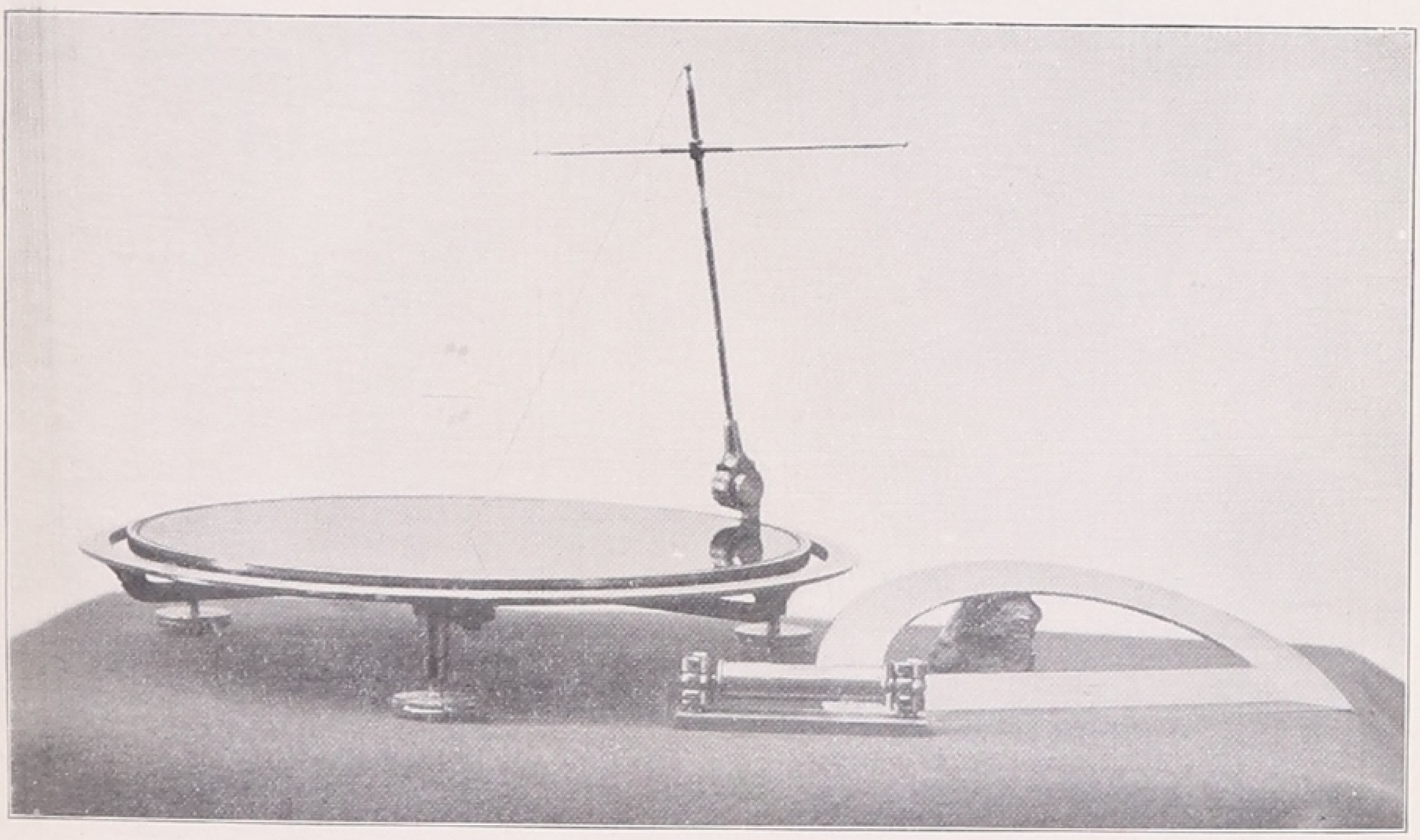

FIG. 2.—THE MARVIN NEPHOSCOPE.

[Mirror with attachments, by means of which direction and relative velocity of cloud motions can be determined. Used at the Weather Bureau stations during the International Cloud Survey of 1896-97.]

FIG. 1.—PREPARING TO FLY WEATHER BUREAU KITE.

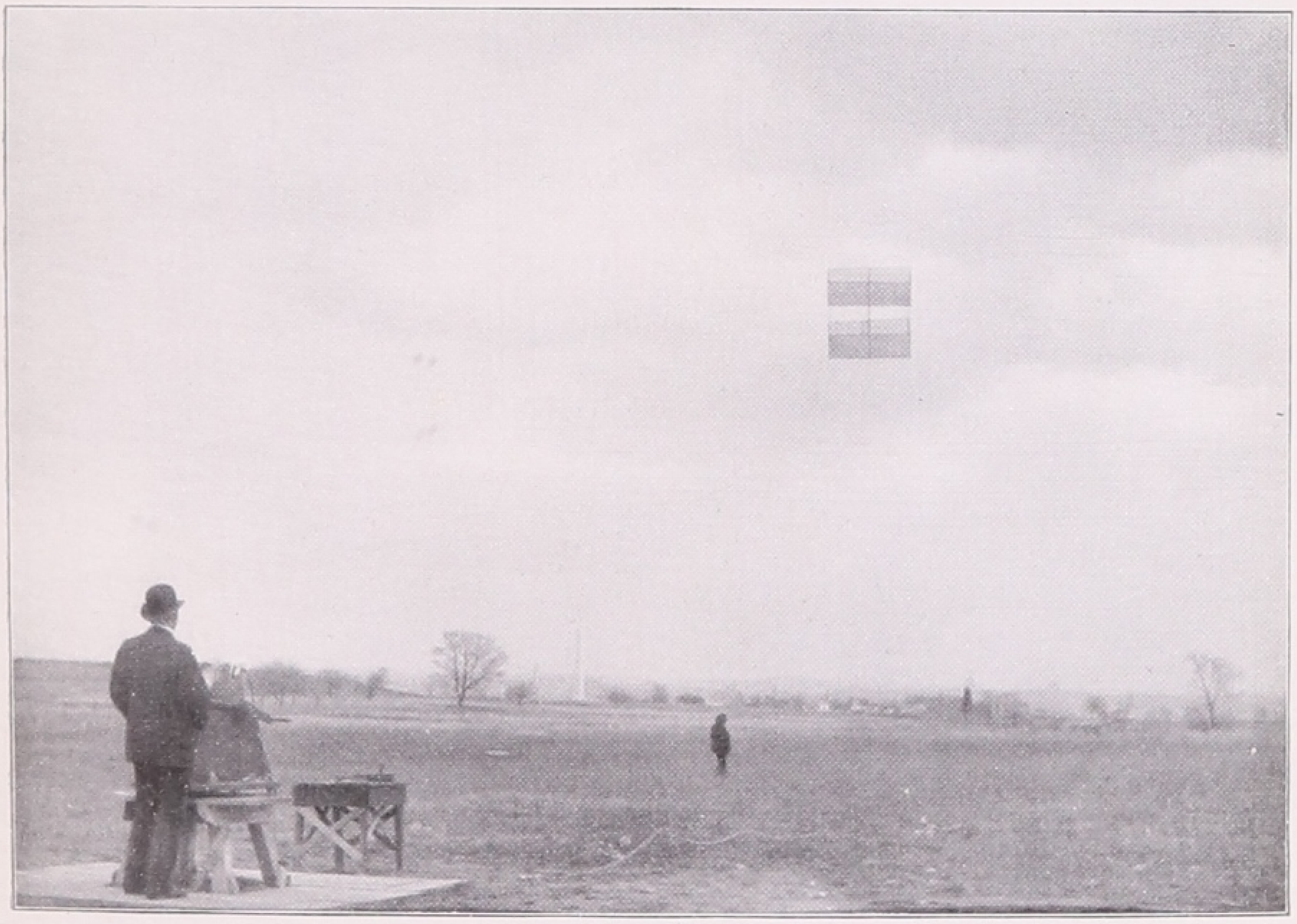

FIG. 2 —WEATHER BUREAU KITE IN THE AIR.

[The kites shown are cellular or Hargrave, which have been perfected by the Weather Bureau. They fly with great steadiness, and are held by a fine steel wire and iron reel at the ground. A single kite has ascended to 8,000 feet, and several kites in series have risen to 13,000 or 14,000 feet.]

stations on the circuit; by an ingenious arrangement of the order of transmission of the circuit messages not only Washington, D. C., but many other cities have the exact weather records furnished for the hour of the observations; this has become quite necessary, because at many of the large cities weather maps are constructed and printed similar to the one in Washington, D. C., and which, though the latter is somewhat larger and more complete, practically contain the same important information; from many local centers the Washington forecast and the map itself are distributed to an enormous population and displayed in all the most important places of business and in the schools and private institutions. The third arrangement required was a method of reducing the expense of telegraphic messages to a minimum, since the actual cost of transmitting so many million words per year is an exceedingly heavy item; this has been done by constructing a compact and ingenious cipher code which can be readily translated, and in which five or six words give all the data which would otherwise require twenty-five or thirty words; the bill for telegrams alone under this cipher code is about $180,000 annually, and it may be readily inferred how great is the saving to the public in this direction.

Furthermore, the Annual Reports contain a complete statistical statement of all the important meteorological records made at the telegraphing stations, compiled so as to give the normal values of the pressure, temperature, precipitation, and wind movements. These statements have been continued from year to year in the same form, and it is now proposed to combine them into a complete scheme of normals based upon the work of the past quarter of a century. If such normals can be formed at intervals of twenty-five years, many questions regarding the long-range variations of the climate and weather will be finally answered for the benefit of future generations. When we reflect that astronomers have been engaged for several centuries in constructing the mean values upon which the larger questions of the structure of the universe depend, it may not be amiss for meteorologists to patiently continue a campaign as far-reaching as that of the astronomers in its outlook.

The discovery of the laws affecting the seasonal changes would certainly be of such benefit to mankind, in the complex civilization upon which modern life is entering, as to justify the expense and the patient labor involved in such a contribution from each generation to its successor. The crude method of tilling the soil common in these days will certainly give way to an exact economical procedure, based largely upon the result of meteorological research, increasing in precision with the lapse of time. There already exists in the archives of the Weather Bureau an immense quantity of valuable material calculated to serve these purposes. The great mass of weather observations, the collection of which is characteristic of this branch of science, is being systematically studied and condensed year by year in the records division, so that, before the original records are placed in the fireproof vaults, the central facts are extracted and appear annually in the report of the chief of the Bureau.

The expert investigator must be intrusted with the work of discussing the results in special researches, and the Annual Report contains a series of valuable papers drawn up on these lines. Thus, there have been published papers on the laws of storms; the physical processes in the air; the climatic conditions; the relation of crops to the weather; atmospheric electricity; terrestrial and solar magnetism; auroras; eclipses of the sun; Ferrel's treatises; Langley's researches on the solar constants; Abbe's translations; instruments and cloud studies; Bigelow's reports on magnetism, storm tracks, and the international cloud observations; a series of professional papers containing reduction tables in all branches of the subject; scientific notices; and a set of scientific bulletins on a variety of subjects. The Annual Reports also contain the results of the great work of the international simultaneous observations over the Northern Hemisphere, which were inaugurated by General Myer and published from January 1, 1875, to June 30, 1889. This vast series of observations has been compiled in a set of valuable charts and distributed in recent years, but it is believed that too little research work has been done to bring out the laws which are contained within these records. There is also an account of the international polar expeditions of 1882–83, when General Greely had charge of the American expedition to Fort Conger and Lieutenant Ray of that to Point Barrow.

THE MONTHLY WEATHER REVIEW.

Another important method of instructing the public in the science of meteorology has been the regular publication of the Monthly Weather Review, first issued for January, 1873, which was extended backward to July, 1872, and reprinted in the annual volume. For the next ten years these Reviews were reprinted in the Annual Report itself, but since 1884 they have appeared as a separate publication only. The Monthly Weather Review has regularly contained an accurate description of the incidents connected with the severe storms which have developed in the United States, giving the facts regarding warnings issued by the Bureau, the path of the storm and its intensity, and the damage inflicted, if important; the tracts of the high and low pressure areas across the country have been carefully charted from month to month; there are details of all the other important weather phenomena, and the weather record of several thousand volunteer observers, who are gradually constructing the complete climatological data for the normals and abnormals of temperature and precipitation; important reports on scientific research have usually been included in this publication, and they still form an occasional feature; in late years a series of interesting short notes of a more popular character has added to the value and popularity of the publication.

THE LIBRARY.

It may be stated in connection with this subject that the library of the Weather Bureau has grown steadily since 1870 at the rate of about 700 titles a year, till we now have something like 17,000 books and 3,000 pamphlets. The collection is strong in strictly meteorological data, and it is fairly complete in the department of physics and in the current periodical scientific literature. The library is provided with a card catalogue, an extensive bibliography of meteorology, and a foreign index of scientific titles.

THE CLIMATE AND CROP BULLETINS.

At the very beginning of the operations of the Signal Office a strong effort was made to obtain the active cooperation and support of the agricultural societies of the country and the boards of trade of the cities, who should, it was proposed, in conference with the chief, devise plans for practical weather work, and by missionary efforts in their respective communities should interest the people in meteorology, as well as instruct them in the utility of the national service. In the report of 1872 is contained a long list of such cooperating organizations. This system of mutual support was of the greatest value in establishing the weather service firmly among the necessary adjuncts of our modern life; but the important fact to note is that this beginning soon consolidated into one of the most important permanent features of the service. Such a development of local activity in the several States led to the establishment of the system of State weather services. There had been a few detached attempts by the different States, New York (1825), Pennsylvania (1837), Massachusetts (1849), Iowa (1875), and Missouri (1876), to apply local funds to the study of problems of interest to the special districts, having particular reference to the agricultural requirements and a knowledge of the effect of the climate upon crops. The experience of ten years with the national service showed that it could be efficiently supplemented by the addition of reports from each county in every State of the temperatūre, the rainfall, and the conditions and need of the crops. On the proposal of Lieut. H. H. C. Dunwoody and Professor Abbe such a cooperation was organized with the States, which one after the other took up the plan.

In 1881 the scheme was formally begun, and it has developed into the useful work now carried on by the climate and crop division of the Weather Bureau. The work consists in collecting by telegraph or postal card the required information and discussing the same prior to publication. This takes two forms, the compilation of special monthly reports by the several States and Territories, and the construction of weekly reports by the national Weather Bureau. The monthly reports by States at first were incomplete so far as the total number of States was concerned, and the style of the publications was very irregular when compared together and sometimes unsatisfactory. As the result of Professor Moore's efforts to secure uniformity these faults have at last been remedied, and nearly every section now publishes, in a uniform type and size, a monthly report of the climate of its region. In 1887 the Signal Service began to publish the national Climate and Crop Bulletin, giving each week an account of the conditions of all agricultural interests of the country. At first it contained about 600 words, with a summary of the general weather, and especially of the temperature and rainfall; then statements regarding the progress in farm work and the effects of weather on the crops were added, the reports being derived originally from the farmers themselves. In 1891 the Bulletin was enlarged and improved by adding two charts, showing the variation of the temperature and rainfall from the average normal conditions in the several districts for the week of issue; in 1891 brief telegraphic reports from the several States giving the condition and prospect of the crops were made a regular feature of the preparation; in 1894 two more charts, the temperature extremes and the total rainfall, were added; the Bulletin, therefore, now contains four charts, a general summary of the weather, and brief reports on the condition of the crops for each State. The climate and crop service as at present organized has forty-four sections, including Puerto Rico and Cuba, and utilizes 13,000 mail reports, furnished by more than 3,000 voluntary observers. Each section, besides providing material by telegraph for the national Weekly Bulletin, issues a local bulletin, in which the climatic conditions are fully and accurately described. It is obvious that such records must ultimately make the climate of the United States a subject of exact knowledge, and that in the future the most successful farming will take it into account.

THE DAILY WEATHER MAP AND FORECAST.

Besides the special, the annual, the monthly, and the weekly reports another most important publication remains to be mentioned. This is the Daily Weather Map. The primary object in establishing the weather service of the United States was the issuing of warnings of the approach of storms and floods for the benefit of commerce and transportation, though, as already shown, it logically was extended to cover the agricultural interests in the most complete form possible.

These warnings must be based upon simultaneous observations taken at stated hours, collected with the utmost rapidity, transferred to charts, studied and discussed by practical experts, who, by their knowledge of the weather laws, should give the best interpretation to the conditions in the form of forecasts. The daily weather report consists of four parts: (1) The bulletin of the weather conditions, pressure, temperature, rainfall, and wind direction and velocity; (2) a map displaying the isobars, isotherms, wind direction, state of the sky, areas of rain and snowfall during the past twelve hours, storm signals, cold-wave signals, and thunderstorms; (3) a synopsis of the general weather conditions of the United States; (4) a detailed forecast for the several regions of the country. These daily maps were issued originally November 1, 1870, as the "Weather bulletin," being at first made by a new manifold process, and they were published in the daily newspapers of many cities. About March, 1872, they began to be reprinted under the title "Daily bulletin of weather reports, with synopsis, probabilities, and facts." Subsequently a small-sized weather chart was added, being printed by lithography.

In the course of 1872 the scope of the map was enlarged, and it soon contained the original data of observations, the isobars, isotherms, synopsis, and probabilities. The reports of the river stages appear regularly on the same sheet; also an account of the storm signals, cold-wave signals, frost warnings, local storm warnings, and other phenomena of importance to the public. Almost at the outset the system of observations for the United States embraced the Canadian provinces; rather irregular reports were received from the West Indies during the hurricane season, until May, 1898, when a regular permanent service was established throughout that region. During the first years of the work three daily maps were prepared, made up from observations taken at 7.35 a. m., 4.35 p. m., and 11.35 p. m., Washington time, thus dividing the day into periods of about eight hours. This tridaily series of maps was changed in 1888 to a bidaily series, taken at 8 a. m. and 8 p. m., all times being those of the seventy-fifth meridian. In 1895 the printing of copies of the evening maps was suspended at Washington, D. C., and now the published maps at Washington City and the other large distributing centers are made from only the morning observations. The observations were made at less than 50 stations in 1871, but this number was increased in a few years to 150 stations, which sufficiently cover the territory under consideration to record all the general conditions of the atmosphere. The distribution of the resulting morning forecasts begins in less than two hours after the instruments are read, first by telegraph and telephone to about 1,000 centers of distribution, thence by telephone, mail, and railway-train service to more than 73,000 addresses, the greater part being delivered early in the day, and none later than 6 p. m. Besides these 1,000 telegraph distributing centers, the forecasts are telegraphed, at Government expense, to about 1,800 additional places, to be communicated to the public by means of visual and sound signals, the former consisting mainly of flags and the latter of steam whistles. At the telegraph distributing centers an immense number of the forecast messages are quickly printed by hand stamp and logotypes on postal cards bearing an official frank. These are mailed to all communities that can be reached not later than 6 p. m. of the day of issue, and suitably posted for the benefit of the public.

There is, besides, an additional system of distribution, by which more than 8,000 stations are furnished by telegraph at Government expense, as occasion justifies, with the "emergency warnings," that is, for hurricanes, cold waves, frosts, or local storms of unusual severity.

With this effective system, which is being extended and improved as opportunity affords, there is scarcely a community in the entire country that does not receive the benefit of the forecasts of the Weather Bureau. As soon as the forecasts are prepared they are sent to the press associations, through which they reach all important newspapers and are thereby given an almost unlimited circulation through the country. The morning forecast only is used for visual and sound signals; in the bulletin displays by the various means of distribution the morning forecast is also mainly used, the prediction applying more particularly to the following day. The evening forecast is published in the morning newspapers of the succeeding day and the morning forecast in the evening papers of the same day on which the forecast is made. A system of special reports from stations, in cases of unusual weather conditions in any district, supplement the regular observations, whereby the progress of a storm may be more closely followed. Special bulletins are also issued detailing the history of a hurricane or violent cyclone along the most important portions of its track. The verification of the forecasts shows that on the average about 82 per cent are strictly correct. A large portion of the failures are due to minor irregularities in the location of the rainfall or temperature changes, and these are really unimportant to the public. Contrary to general opinion, it is much less difficult to forecast the direction and force of well-defined and even dangerous storms than the common variations of the weather, when the conditions are flat and the course of the weather really uncertain; it is very seldom that any dangerous winds are not timely predicted by the Weather Bureau.

For some years the view prevailed that a local observer could forecast better for his immediate district than the national official at the central office, but after an extensive trial it was found that the Washington City forecasts verified 4 or 5 per cent better than the local forecasts, and the local system was therefore abandoned. It is difficult to obtain any very exact account of the actual saving of property to the public as the result of these storm warnings, but it is everywhere agreed that it amounts annually to a very large sum. The direct cost of the weather service to the people has for several years been less than $1,000,000 annually, and those in the best position to judge believe that the salvages alone would cover the expense of the work. This is quite independent of the many advantages accruing to our civilization from the agencies above described for serving the public in an agricultural, commercial, and educational way. The committees of Congress which are charged with inspecting the money value of the estimates are in many instances ready to recommend the appropriation of more money than even the chief of the Bureau or the Secretary of Agriculture asks for. Another fact is that there has been a steady natural growth in the operations and in satisfying the legitimate needs of the public, so that the people see for themselves the practical advantages of this great scientific work.

CONTRIBUTIONS OF THE WEATHER BUREAU TO METEOROLOGY.

The Weather Bureau has always sought to bring its methods to the knowledge of the public by courteously explaining the details of forecasting to all visitors at the central or local offices. It has made very creditable exhibitions at the world's fairs at Philadelphia, Chicago, New Orleans, Atlanta, Omaha, and Paris. It has put itself in line with all the great international reforms by advocating and adopting international standards of measures and standard time for its observations. It has organized the international simultaneous observations of 1875–1887, and cooperated in the international polar expeditions of 1881–1883, and in the international cloud observations of 1896–97. It has sent delegates to European meteorological congresses. It has contributed to meteorology several standard memoirs—Ferrel's "Professional papers," Nos. 8, 12, and 13, his "Recent advances," his reports on "Psychrometry," and on "Reduction to sea level;" Abbe's "Meteorological apparatus and methods," his "Storm and weather predictions," his two "Collections of translations;" Marvin's reports on instruments of various kinds and on kites; Bigelow's reports on magnetism, on storms and storm tracks, and on clouds; and reports by Mendenhall on atmospheric electricity, by Finley on tornadoes, by Henry on rainfall, by Hazen on thunderstorms, by McAdie on lightning; besides a multitude of minor papers of every kind. Special observations at the higher levels of the atmosphere have been made by means of the mountain stations—Mount Washington, Mount Mitchell, Pikes Peak; by cloud heights with theodolites; by kite ascensions, and by eleven balloon voyages. Several series of hourly observations are regularly taken of all the meteorological elements; the vertical gradients of the pressure, temperature, and vapor have been discussed by several methods; a great deal of attention has been given to plateau barometry, together with the determination of the elevation of the stations throughout the United States, and the instrumental and atmospheric corrections. The dynamic problem of the motions of the atmosphere is kept steadily in view, and advances are being made from time to time in this most important subject.

LATEST VIEWS ON THE THEORIES OF THE ORIGIN OF STORMS.

Perhaps it may be well to close this paper by stating the latest views on the theories of the origin of storms, which have been discussed by means of nearly every conceivable hypothesis during the past fifty years. The question involved has been how much emphasis should be given to the horizontal dynamical action of the large general currents of the atmosphere, due to the polar-tropic differences of temperature, and how much to the local vertical convectional action due to surface heating. Some meteorologists have laid stress upon one of these theories, and others upon the other, but, as in the Redfield-Espy controversy regarding the circular and the radial components of motion, it is now seen that both are efficiently in operation, though the circular dominates in intensity; so, while both the horizontal dynamic forces and the vertical convection are actively concerned in the structure of storm circulations, it is the former which preponderates, that is to say, local cyclones are but minor whirls in the general atmospheric circulation, which is continuously striving to reduce the difference of temperature of the atmosphere between the Tropics and the polar regions; also they are sometimes strengthened by the evolution of the latent heat of precipitation. The vertical currents in cyclones and anticyclones are primarily components of vortex motion, and these serve to set in operation the thermo-dynamic processes concerned in the making of clouds and rain or snow fall. The larger questions of meteorology concerning the slow seasonal variations, which depend upon special solar actions, and which mark the effect of solar energy expended in its most delicate and subtle forms, must require, like the large problems of astronomy regarding the structure of our solar system and the universe of stars, a considerable expenditure of labor and the lapse of no little time to arrive at an ultimate solution. Each generation has therefore imposed upon itself, in meteorology, as in astronomy, the duty of faithfully collecting observations of the phenomena as they occur in their day. In view of the distinct practical return which the Weather Bureau has been able to make to the public for the expense of its maintenance there has never been any disposition on the part of the people to omit to provide for such current scientific researches as the benefit of future generations seems to call for.

SOME EXAMPLES OF THE DEVELOPMENT OF KNOWLEDGE CONCERNING ANIMAL DISEASES.

By D. E. Salmon, D. V. M.,
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INTRODUCTION.

The acquirement of knowledge in the domain of animal diseases during the century now closing has been constant and amazing, and compares favorably with the advancement in other branches of science which, with the zeal and activity of investigators, has attracted the wonder and admiration of the world. While something is known even to the general reader of the progress of knowledge in this field, and of the usefulness of this knowledge in explaining and preventing the diseases of man, there are comparatively few who have an adequate conception of the vast array of facts which have been accumulated and the revolution which these facts have brought in the prevailing ideas as to the nature of the various diseases and the methods by which they should be treated. To enter into all the details of the development of this subject during the century would require the writing of a series of volumes on the respective subdivisions, which, when completed, would be of professional rather than popular interest. A review of this character is manifestly impossible, even if such detail were desirable, in a Yearbook paper. The writer, therefore, deems it wise to confine himself to the work that has been done upon a few great problems which are, or should be, of interest to the many, and the elucidation of which has done most to ameliorate the condition of mankind as well as that of the domesticated animals.

The beginning of the nineteenth century almost defines the line at which the old and fantastic doctrines on animal pathology began to crumble and to be replaced by facts and scientific principles. Previous to that time a more or less elaborate system had been compiled, based upon observations made during the past history of the world; but as the ideas in regard to the structure and activities of the animal body were in many cases crude and erroneous, it is not surprising that the conceptions of disease were often distorted and strange, as viewed from the standpoint of our present knowledge. What is it that has brought light out of the darkness and order out of the chaos of the preceding centuries? What new factor, what change of method, was introduced with this century which accounts for the overthrow of the old doctrines that had been built up from the world's previous experience, and the substitution for these doctrines of definite and accurate knowledge? The answer to these questions is as interesting as the story of the achievements, and is of particular value at the present time. It should be a guide to us in directing the forces that will in all human probability make the twentieth century even more glorious in its accomplishments than the one which preceded it. The purpose of this paper is, therefore, not only to show the great strides of progress, but to indicate how this progress has been made.

INEFFECTIVENESS OF OBSERVATION WITHOUT EXPERIMENTATION.

It was in the early part of the seventeenth century that Bacon pointed out the weakness of the old speculative philosophy which built a great superstructure of doctrine or theory upon a foundation having a minimum of substantial fact and evidence. Such structures were without stability; they represented the individual workings of the philosopher's mind rather than the truths of nature, and for that reason they were constantly toppling over, to be replaced by another philosophic effort no more substantial than the first. Although Bacon at that time clearly demonstrated the necessity of first gathering all available facts and of interpreting these without preconceived bias by the inductive method, it was long before these teachings had their legitimate influence, either in human or veterinary medicine, and they are by no means universally accepted, outside of the scientific world, even at the present day.

The great question has always been, How are the facts relating to any branch of natural science to be obtained? The philosophers of the old school said, "by observation and deduction;" and they have their followers to-day who seek to direct, through legislative enactment, that physiological and pathological investigations shall be limited to "observation." But, if there is one great truth which stands out more prominently than others in the history of the progress of science, it is that observation, as contrasted with experimentation, is of itself insufficient to solve the problems or lead to an accurate comprehension of the facts.

EFFORTS TO DISCOVER THE CIRCULATION OF THE BLOOD BY OBSERVATION.

The insufficiency of observation without experimentation is demonstrated by the long-continued efforts to discover and explain the action and use of the heart, the arteries, the veins, and the blood. For hundreds of years the anxious students of physiology had made observations upon the living and the dead subject, but the mystery, ever elusive, had baffled the keenest vision. Thus, Hippocrates (460 B. C.) knew something of the movement of the blood. Aristotle (384 B. C.) taught that in man and the higher animals the blood was elaborated from the food in the liver, thence carried to the heart, and sent by this organ through the veins over the body. Praxagoras of Cos (341 B. C.) distinguished the arteries from the veins and regarded the former as air vessels. Erasistratus (304 B. C.) and Herophilus, of the Alexandrian school, taught that, while the veins carried blood from the heart to the organs of the body, the arteries carried a subtle kind of air or spirit. Galen (130 A. D.) discovered that the arteries were not merely air pipes, but contained blood. Servetus (1553) added to this knowledge the belief that the blood flowed from the heart to the lungs and from the lungs back to the heart. Thus, the studies and observations of two thousand years had only given a very incomplete and inaccurate idea of the circulation, leaving the great central fact of the heart's influence unknown and unsuspected.

HARVEY'S EXPERIMENTS FOR THE DISCOVERY OF THE MOVEMENTS OF THE HEART AND BLOOD.

It remained for Harvey (1578–1657), the great contemporary of Bacon, to elucidate the subject most thoroughly by a long series of experiments upon living animals. He tells us that he began his investigations into the movements of the heart and blood by experimenting and seeing the phenomena in living animals. He minutely described what he saw in pigs, dogs, serpents, frogs, and fishes. He even made use of slugs, oysters, lobsters, and insects, and lastly of the chick while still in the shell. He particularly described his observations and experiments on the ventricles, the auricles, the arteries, and the veins. He explained the mechanism of the valves in the veins, showing that their function was not to moderate the flow of blood from the heart, as Fabricius believed, but to favor its return to the heart. He clearly demonstrated the effect of obstruction of the blood stream in arteries and veins by the forceps in the case of a snake and by a ligature on the arm of a man. He proved that it is the contraction, not the dilation, of the heart that coincides with the pulse; that the pulse is not produced by the arteries expanding and filling themselves, but by the blood being forced into them and causing their enlargement; that there are no pores in the septum of the heart, and that all of the blood in the right ventricle is sent to the lungs and returned by the pulmonary veins to the left side of the heart, being forced again by the left ventricle into the arteries, round by the smaller veins into the venæ cavæ, through which it is brought back to the right side of the heart, making a complete circulation; that the blood in the arteries and that in the veins is the same blood; that the action of the right and left sides of the heart, auricles, ventricles, and valves, is the same, the mechanism in both being for the reception and propulsion of liquid and not of air; that there is no to-and-fro undulation in the veins, but a constant stream; that the dynamical starting point of the blood is the heart and not the liver. (Pye-Smith.)

All of these conclusions were revolutionary in their effect upon the doctrines of the times, and thus Harvey, by a few years of experimentation, completed the solution of this great problem, and contributed more in the way of definite facts to sustain his views and to clearly explain the phenomena of the circulation than had been furnished by all his predecessors from Hippocrates to his own time.

COMMENCEMENT OF SYSTEMATIC STUDY IN VETERINARY SCIENCE.

It was not until after the middle of the eighteenth century that veterinary schools were established and systematic instruction in animal pathology was commenced. Previous to that time there had been published some remarkable treatises on the diseases of animals, but the building up of the science may be said to have had its beginning at the foundation of the schools dedicated to the investigation and teaching of veterinary medicine. The first veterinary school was established at Lyons, France, in 1761; the second at Alfort, near Paris, in 1765. These were followed by one at Copenhagen, in 1773; Vienna, in 1775; Berlin, in 1790, and London, in 1791.

The beginning of the nineteenth century, therefore, found veterinary instruction in progress in the principal countries of Europe, and considerable literature suitable for text-books was already accessible. The study of the subject was stimulated not only by the establishment of the schools, but by the invasion of deadly epizootics, which had followed the course of the armies to all parts of the Continent and which threatened the annihilation of the domesticated animals. Knowledge of these plagues and the best means of controlling them had become essential to the existence of animal husbandry and the maintenance of the food supply. The accumulation of facts and correct views concerning these diseases was the greatest task of the veterinary profession, and the progress of this work is perhaps the best general indication that can be accepted in regard to the development of animal pathology.

GLANDERS AND FARCY.

One of the most terrible plagues of equine animals is called glanders when it affects the air passages and lungs, and farcy when it appears upon the skin. The principal symptoms are a discharge from the nose, ulceration of the inside of the nasal passages, particularly of the septum, enlargement of the glands under the jaw, and pustules of the skin. This disease, from which there is seldom recovery, was known to the Greek and Latin writers as one of the most serious diseases of horses and asses, and its contagiousness was quite generally admitted.

EARLY VIEWS REGARDING GLANDERS.

About 1749 the elder Lafosse, of Paris, began to teach the spontaneous origin of glanders, and endeavored to show from theoretical considerations and clinical observation that this was a purely local disease of an inflammatory nature and could not be contagious. At first this view was combated by many practitioners and by the veterinary schools, but being in harmony with certain medical doctrines it gained adherents, was taken up by the Alfort school, at first timidly and later with all the energy and eloquence of Renault, Delafond, and H. Bouley, and became predominant in France and perhaps also in Germany.

Renault thought that the disease might originate as a consequence of the absorption of pus from suppurating surfaces or abscesses, and this view was largely accepted. H. Bouley substituted the hypothesis that its origin was due to the exhaustion of the vital forces as a result of bad hygienic conditions or excessive work. Those who specified instances where the disease spread from an affected horse to others were met by the citation of instances where it did not spread. As H. Bouley afterwards admitted, the advocates of the hypothesis of noncontagion and spontaneous generation, by a singular disposition of mind, believed themselves authorized to invoke against the facts which proved contagion other facts where contagion did not result. This was the consequence of wrong methods of investigation and of improper use of evidence. Positive evidence establishes a fact: negative evidence can not overthrow positive evidence. It was by not understanding this apparently axiomatic proposition that the erroneous views in regard to the causation of glanders were so widely accepted and did so much harm.

The veterinarians of France, especially those of the army, were largely from the Alfort school, and, acting upon the teachings which they had received, they no longer treated glanders as a contagious disease, but permitted the retention of diseased animals and allowed these to be stabled with healthy ones without precautions to guard against communication. The inevitable happened, and the continental countries were overrun with glanders. The cavalry horses in particular were decimated, and thousands that became useless for the army were sold to civilians and served to propagate the contagion upon the farms, the very fountain head of the equine supply. From 1830 to 1840 the condition was almost intolerable, and the disease was becoming more and more prevalent. Those observers who believed the disease due to contagion were everywhere met by others equally sincere and able who believed it of spontaneous origin. It is a striking example of the difficulties of settling such questions by clinical observation alone.

EXPERIMENTS REGARDING THE CONTAGIOUSNESS OF GLANDERS.

In November, 1836, the French war department undertook to have the question of the contagiousness of glanders settled by experimental investigation. A commission was appointed, the members of which were mostly partisans of the doctrine of noncontagion, and evidently strongly biased, for after more than three years' investigation, in which 138 healthy horses were used, they were still unable to reach a decision. The minister of war then added to the commission a number of eminent men, members of the Academy of Sciences, who came with unprejudiced minds and a scientific spirit to the study of this important problem.

In 1837 an incident had occurred which had served to check to a certain extent the enthusiasm of those who denied the contagiousness of the disease. In this year Rayer recognized that a man who came under his observation was affected with a disease resembling glanders. Such cases, it appears, were not uncommon, but had been designated as putrid, or adynamic, fever. Investigation developed two facts of importance: First, the subject was a stable man, and as such had been intimately associated with horses; secondly, some of the horses which had been under his care were ascertained to be affected with glanders. This was strongly corroborative of Rayer's diagnosis, but it was not sufficient to meet the arguments of those who thought otherwise. Might not the occupation of the man and the presence of glandered horses be simply coincidences and without bearing upon the origin of the disease? It was necessary to prove the identity of the disease in the man with the well-known glanders of the horse. How was this to be done? Obviously not by disputation or by clinical observation, for these methods were incapable of reaching a definite and incontestable decision. There was but one course that had in it the promise of success, and that was experimentation. If the disease with which the groom was affected could be inoculated upon a horse, and if this horse developed the characteristic symptoms of glanders, then this would constitute a demonstration that the man was suffering from the equine disease. Fortunately for science and for humanity, this test was made. The liquids from the diseased regions of the man proved extremely virulent when inoculated upon the horse, and the disease which developed was glanders with all its well-known characteristics.

Rayer, who had investigated this case of glanders in man, was added to the commission of inquiry, as was also the well-known Boussingault. The strongest partisans of noncontagion were Renault and Magendie, both members of the commission. October 8, 1841, ten horses, carefully selected and perfectly healthy, were stabled with eleven other horses which presented the symptoms of chronic glanders. Each of the healthy animals was placed between two diseased ones, in order to intensify the contagion to which they were exposed, in case such contagion existed. Only eleven days had passed when four of the healthy horses presented symptoms which indicated that they had been infected. On November 22 there were only two horses remaining which did not show symptoms of infection. December 4 glanders with all its characteristics had developed in one of the horses, and by February 11 three more horses were in the same condition. As a result of about four months' close association nine out of ten healthy horses showed symptoms of glanders, and with four of these the disease was so fully developed as to be entirely characteristic.

The commission caused two of these horses to be killed, and on post-mortem examination found all the lesions of chronic glanders. The mucous membrane of the trachea and bronchi was covered with ulcerations, among which were found cicatrices, which Renault believed justified him in suspecting that the animals had been affected before the beginning of the experiment. However slight may have been the grounds for doubt, after the first experiment, it was decided that another test should be made. This was commenced April 11, 1842, with seven selected horses, which were placed two by two in the stables, so that each healthy horse would come in contact only upon one side with a glandered horse. By August 7 glanders had developed in every one of these experimental animals.

Just previous to these last-mentioned investigations, that is, in 1840, a special commission composed of officers of the different branches of the cavalry service, which had been charged to submit a plan of a model stable in which should be united the most advantageous hygienic conditions, made a report attributing the development of glanders among cavalry horses to the unsanitary conditions of the stables. An academic commission reported by the younger Bouley held the same opinion and thought that the bad construction of the cavalry quarters, the unhealthfulness of the stables, the crowding of the animals, and the vitiation of the atmosphere should be placed among the principal causes of what was called spontaneous glanders. Contagion, the true cause of the disease, was left out of consideration or given an entirely subordinate position, while attention was concentrated upon conditions which, at most, could but favor, to a certain extent, the propagation of the infection. Does not this bring to mind the contentions now being made by those who wish to find the cause of tuberculosis in some other agency than contagion and who invoke the influence of the identical conditions which the French military commission of 1840 found sufficient to explain the origin of glanders? H. Bouley, one of the most able contestants of the theory of contagion, and who afterwards frankly admitted his error, says in regard to the project for eradicating the disease by reconstructing the stables:

> If the certainty had been acquired, as it has been to-day, that contagion alone was the cause, and that to guard against it was sufficient to avoid the ruinous losses which glanders then occasioned, there is no doubt that the reconstructions proposed would not have been undertaken, or, at least, that they would have been upon a smaller scale and the expenses distributed over a larger number of years.

CONTAGIOUSNESS OF GLANDERS DETERMINED AND EFFORTS TO CONTROL THE DISEASE.

One other question remained to be solved. It was held by some that acute glanders might be contagious, while the chronic form, that usually encountered in the horse, could not be communicated. In the experiments which have been already mentioned the persons who held to this opinion thought that the contagion was explained by the disease having assumed an acute form in some of the animals to which exposure had been made. To answer this contention Saint-Cyr made a series of inoculation experiments, reported in 1863, from which he concluded:

Under all its forms, in all its degrees, in all its conditions, in all its stages, and, finally, at every instant of its existence, glanders is contagious; and there is always danger of contagion, not possible, eventual, or conditional danger, but certain, actual, and always menacing danger.

This ended, in France, the contest over the contagiousness of glanders. A similar difference of opinion had existed in other countries, especially in Germany, but the problem was solved for all by experimental exposures to the contagion or by inoculation. Without these experiments upon living animals it is impossible to conceive how the views of those who interpreted differently the facts of observation could have been harmonized; and in the presence of doubt on the essential question of contagion or spontaneous origin, there was and always would have been hesitation and lack of thoroughness in applying preventive measures and in enforcing regulations for eradicating the disease.

After settling the question of contagion there were still two great problems which confronted the veterinarian in his efforts to control this disease. The first of these related to the cause of the disease; and while there was ignorance in regard to this it was impossible to have an intelligent comprehension of the conditions under which the contagion survived or of the kind and strength of disinfectants required for its destruction. This problem was solved simultaneously during the year 1882 by Bouchard, Capitan, and Charrin, in France, and by Loeffler and Schuetz, in Germany. Here, again, inoculation experiments were absolutely necessary to demonstrate that the suspected bacillus was the cause of the disease. Numerous forms of bacteria are usually obtained by making cultures from virulent material, and there is no way of learning which variety produces the disease except by making the trial, that is, by inoculating susceptible animals with a pure culture of each of these microorganisms. In that manner the bacillus of glanders, now known as the *Bacillus mallei*, was proved to be the active agent of the contagion, and the acquisition of this fact has brought with it a flood of light that has served to clear up the doubt and confusion of earlier years.

The second great problem was to find a speedy and certain method of diagnosing the disease. Glanders with horses is usually a chronic malady, which in its first stages presents very slight and indefinite symptoms that are entirely insufficient to enable the observer to state positively that the animal is affected with this dangerous and fatal disease. Nevertheless, the disease is contagious at that period and is liable to be disseminated to other horses and to the attendants; indeed, it is the animals that have failed to develop characteristic symptoms which are most dangerous, since very often they are not even suspected as sources of contagion. Sometimes affected horses live for several years in this condition, and attention is only attracted to them finally because a series of horses which have been exposed to them have successively developed the disease. Even after such horses were suspected it was a most difficult and embarrassing matter for the veterinarian to produce sufficient evidence to warrant their destruction, particularly if they happened to be valuable or if the owners were attached to them. This difficulty of diagnosis was largely responsible for the continuance of the contagion, and it was especially felt in large stables containing many horses and where it was consequently essential to successful treatment to have every affected animal removed.

The first efforts to aid clinical observation in making a diagnosis were by inoculation. Either the suspected horse was inoculated with its own nasal discharge (auto-inoculation) or another individual of the equine species was used for this purpose. Very often satisfactory evidence of glanders could be obtained in this way, but in far too many cases the results were uncertain or unreliable. With the bacteriological studies and the inoculation of small animals came the knowledge that the guinea pig was very sensitive to this contagion, and that, if inoculated in a proper manner, it would present characteristic symptoms in a few days. This was an extremely valuable discovery, and where only one or at most a small number of horses were suspected, it made it possible for the veterinarian to reach a quick and reliable decision.

JUSTIFIABLENESS OF INOCULATIONS IN GLANDERS.

The question is now raised as to whether these inoculations are justifiable, and the antivivisection societies, with many of the humane societies, have joined in an effort to secure legislation to make it a criminal offense to conduct such experiments upon living animals. The ethical questions relating to the alleged wrong of causing suffering to an innocent guinea pig, either for the advancement of science or the diagnosis of a disease, are too broad to receive more than a mere mention in this connection. It may be admitted, however, that so long as we acknowledge the right and the morality of raising animals to be slaughtered for food, and so long as we permit such a painful operation as castration to be performed on millions upon millions of individuals to make them more docile, to cause them to fatten more readily, to improve the quality of the meat—in a word, for the financial profit which arises from the operation—it is inconsistent to deny the propriety of a method of experimentation which in the aggregate has saved much more distress than it has caused and which is essential to the advancement of medical knowledge. In the case which has just been mentioned, for instance, it may be asked whether the practitioner would be justified in leaving a horse suspected of glanders to come in contact with other animals, perhaps to communicate the disease to some human being, when he could definitely decide the question by inoculating two or three guinea pigs. It might be said that a suspected horse should be put in quarantine in order to prevent such untoward consequences, but there are all degrees of suspicion, and a horse can not be quarantined under the law and his owner put to expense and loss without some evidence. It is a question of danger and suffering with men and horses on the one side and with guinea pigs on the other. Under such circumstances the objections appear unworthy of serious consideration.

THE MALLEIN TEST FOR GLANDERS.

Fortunately, a continuation of the experiments with living animals has led to a discovery which largely does away with the necessity of inoculating guinea pigs or other creatures in order to make a diagnosis in the doubtful cases to which reference has been made. In cultivating the bacillus of glanders it was observed that it produced during its growth a toxic substance which, when injected into the tissues of an animal affected with glanders, caused a local swelling and raised the body temperature to such a marked extent as to be of great assistance in making a diagnosis. This toxin is called mallein, and the experiment of injecting it for the purpose of making a diagnosis is called the mallein test. It is particularly useful in cases where a large number of horses which are stabled together have been exposed, and where it is, consequently, of the utmost importance that those which have become infected shall be recognized and removed at the earliest moment. It may not be quite as accurate a test as the inoculation of guinea pigs, but it is more expeditious, less expensive, and saves the guinea pig from dying of glanders, though it may eventually die of some other disease equally painful, even if it does not contract it by inoculation.

In addition to the investigations to which reference has been made, there have been many others yielding much information in regard to the pathological anatomy, histology, and pathology of glanders which for want of space can not receive consideration.

VARIOLA (COWPOX, HORSEPOX).

Some time during the sixth century there was introduced into Europe one of the most horrible and fatal diseases from which mankind has ever suffered. This disease, now known as variola, or smallpox, is no longer greatly feared, but at that time and through the middle ages, and in fact down to the beginning of the nineteenth century, it was a scourge that could neither be avoided nor conquered. Practically every adult person's face showed the scars. One-tenth of the deaths were caused by it. In England in 1796 the death rate reached the highest point, being 18½ in every 100 deaths from all causes. No city or district was long free from it. People exposed themselves to it or were inoculated with the contagion in order to have an attack under as favorable circumstances as possible, and thus secure immunity for the future. Inoculation was of some benefit—often produced a comparatively mild form of the disease and gave immunity; it had the great disadvantages, however, that it frequently caused a fatal attack, and, in all forms, it kept up and spread the contagion.

JENNER'S DISCOVERY OF A PREVENTIVE OF SMALLPOX.

In 1798 Edward Jenner announced his discovery that smallpox might be prevented by inoculation with the virus of cowpox, and that cowpox was identical with a disease of horses known by the farriers as grease, or sore heels. This discovery has been of such enormous advantage to humanity, and there have been so many questions raised relative to the nature of the so-called grease of horses, from which cowpox originates, that it is of unusual interest to inquire how Jenner's discovery was made and what developments in our knowledge of the disease have since occurred.

There is no doubt that there was a popular belief in Jenner's native county of Gloucestershire, England, to the effect that the men and women who milked the cows and who developed the vesicular eruption of "the cow disease," would not afterwards contract smallpox. To what extent this belief was held in that section of England, and whether it existed in other countries, are subjects in regard to which there is little reliable information. It is certain that those physicians of the period who had heard of the belief regarded it as due to an erroneous interpretation of facts, but Jenner's conclusions were accepted so promptly that we are justified in concluding that the skepticism and opposition were not greater than might reasonably be expected toward a similar discovery at the present day.

As an indication of the wonderful change which has been brought about since the introduction of vaccination, the writer has taken the latest mortality statistics compiled by the Marine-Hospital Service, based upon the returns from 1,597 cities and towns in the United States, for the year ending December 31, 1897. The population covered was 22,472,334, the total number of deaths 338,994, the number of deaths from smallpox 44, being in the proportion of 1 to 7,704.

How did Jenner make this discovery? How did he determine that the belief of certain people of his county in the protective power of the cowpox eruption against the dreaded smallpox was more worthy of credence than the opinion of others that it did not have this effect? He accomplished this in the only possible way—by experimentation. A boy was vaccinated from a pustule upon the hand of a milkmaid which had been contracted in milking affected cows. The vaccination produced the pustule so well known at the present day, as the result of this operation. After recovery from the vaccination the boy was inoculated with smallpox virus, an operation then very common in England. From this inoculation there were only the effects usually seen following the inoculation of persons who had recovered from an attack of smallpox.

Jenner went a step further and inoculated another child with virus taken from a pustule upon the teat of a cow in an outbreak of the so-called spontaneous cowpox. This child also developed a pustule at the point of inoculation, with slight general symptoms of illness. Starting from this child many arm-to-arm inoculations were made, proving the characteristic appearance of the disease and that it could be propagated indefinitely.

Jenner also cited the case of a farrier who, in caring for horses affected with a disease called grease, had contracted an eruption of the hands with ulceration and suppuration that was accompanied with quite severe illness. Six years later Jenner inoculated this man at different times upon the arms with smallpox virus and only succeeded in producing slight inflammation, which soon disappeared. An identical observation was made with a farmer who had contracted an eruption by taking care of a horse having this disease of the pasterns called grease. It was also observed that when the horses having this eruption were cared for by the same men who milked the cows the disease was carried by these men and caused the eruption of cowpox.

ORIGIN OF COWPOX.

The belief of Jenner that cowpox originates from the inflammation of the skin of the horse's pastern, properly known as grease, has been generally accepted, and we still find the statement in medical works that grease, or equinia mitis, is the origin of cowpox. Now, what is this grease which is communicable to the cow, and from the cow to man, granting such remarkable immunity from smallpox? The disease known to the veterinarian as grease is a more or less aggravated inflammation of the skin of the heels and adjacent parts of the horse, with cracks and fissures, from which there is an offensive discharge, which looks greasy, but which is really a serous exudation. This inflammation may increase until the whole surface is ulcerated and covered by fleshy exerescences slightly resembling grapes in form, and in this stage was popularly called "the grapes." This disease arises from irritation due to moisture, mud, and filth in contact with the skin of the lower part of the limbs. It is not contagious; inoculation from it produces nothing resembling the vaccine vesicle, and for many years it was a mystery how Jenner could have found in this local and spontaneous disease the origin of cowpox.

In 1802 Dr. Loy, of England, published an "Account of some experiments on the origin of cowpox," in which he stated that the horses which communicate the eruption to the men who groom them have at the commencement of the disease symptoms of fever and marked indisposition, which subsides after the appearance of an eruption upon the heels and upon the skin of the greater part of the body. Loy, desiring to confirm the experiments of Jenner, did not hesitate to inoculate his own brother, with the result that after a few days inflammatory symptoms appeared, followed on the eighth day by a vesicle, with slight symptoms of fever, which continued for a day or two. This eruption had precisely the characters of the true vaccine.

In another experiment Loy inoculated the udder of a cow with clear lymph taken from the heel of an affected horse, which produced a characteristic vaccine vesicle. The limpid fluid from the vesicle on the cow's udder was used to vaccinate a child, and produced a vesicle which completely protected from an inoculation with smallpox virus made on the ninth day. Loy also inoculated directly from the vesicle on the horse to the arm of a child, and successfully produced the vaccine vesicle. From this child three other children were successfully inoculated, and their immunity was afterwards tested by inoculation with smallpox virus. With none of them did the smallpox inoculation produce more than a very slight inflammation, which disappeared by the fifth day.

This extremely valuable work of Loy's appears to have been lost sight of for many years, and veterinarians and physicians sought in vain in the various local affections of horses' feet for the virus of cowpox. Chapped heels, grease, and even fistulas furnished material for unsuccessful inoculations, and some of the ablest men of the first half of the century absolutely denied that cowpox could originate in this manner. This opinion was due to the failure of Jenner to describe the disease of horses from which the virus was obtained, and to the ignorance of the farriers, which led them to confound widely different diseases under the one name of "grease." Loy's description, in which he clearly points out the general symptoms preceding the eruption with the horse, and the appearance of vesicles on various parts of the surface of the body, should have been an indication of the cause of failure, but did not attract attention at the time.

The great veterinarians of England, including Coleman and Percival, denied the existence of a disease of horses which could be communicated to cows and produce cowpox, and it was not until sixty years after the observations and experiments of Jenner and Loy that the mystery was cleared up and the facts demonstrated.

The rediscovery of the variola of the horse was largely accidental.

In the spring of 1860 a number of horses near Toulouse, France, were affected with a disease which seemed to be of an epizootic character; in less than three weeks it appeared in more than a hundred animals. According to Sarrans, the veterinarian in charge, this disease began with a slight fever, soon followed by swelling of the hocks, with heat and tenderness of the skin, and the appearance of many little pustules on the surface of the swollen parts. In three to five days a purulent discharge began, which lasted eight or ten days, during which the inflammatory symptoms gradually disappeared. After this second stage the pustules gradually became dry, and from the fifteenth day the crusts and matted hair began to fall, leaving scars of variable development. The pustules did not appear on the limbs only, but also upon different parts of the body, particularly about the nose, lips, thighs, and vulva.

Sarrans did not recognize in this disease the "grease" of Jenner, but he did observe its contagious character. No cows were affected, because the persons taking care of the horses did not engage in milking, and there was no opportunity for transferring the contagion. It is, therefore, probable that the nature of the malady would not have been discovered had not one of the affected horses been taken to Professor Lafosse, of the Toulouse veterinary school. At the first visit only febrile symptoms could be made out, but eight days later the animal was suffering from lameness, with swelling of the left posterior pastern, which was hot, painful, and covered with pustules, discharging an ammoniacal liquid less fetid than the exudation of grease.

It occurred to Lafosse that this was the acute form of grease, and probably the disease to which Jenner had traced the origin of cowpox. He therefore inoculated the udder of a cow with this equine discharge, which he believed was the product of the initial period of grease (eaux-aux-jambes). The success of this inoculation was complete, and in eight days a pustule appeared at each point where the virus had been inserted. These elevations were large, flat, firm, and circular, with a central depression. There could be no mistake; these pustules were the cowpox of Jenner, drawn from their equine source, and they confirmed the accuracy of the conclusions of that eminent investigator.

In order that the demonstration might be complete, a second cow was inoculated from the pustules of the first, causing a typical cowpox eruption, which was in turn inoculated successfully upon a child and a horse. A second child was inoculated with virus taken from this horse and developed a typical vaccine vesicle. Finally, comparative inoculations were made with virus of equine origin and with the ordinary vaccine, which demonstrated that the former produced larger and better developed vesicles, but which were slower in their evolution than the latter.

HORSEPOX.

There was here satisfactory experimental demonstration that this horse disease was identical with cowpox, but what was the horse disease? Lafosse at first considered it the early stage of the acute form of grease, but as it developed he observed the confluent pustules developing upon the pasterns and fetlocks, and afterwards disseminated over other parts of the body, particularly upon the lips and nose. This differentiated the affection from grease and proved it to be a specific eruptive disease. It was now plain why there had been failure for so many years to obtain the cowpox vesicle by inoculating with the discharge from greasy heels and fistulas of the feet. Two entirely different and distinct diseases had been confounded under the same name.

These unexpected results obtained at Toulouse led H. Bouley, of the Alfort veterinary school, to undertake, in 1863, the inoculation upon the cow of all eruptive diseases of the horse which by chance came under his observation in his daily clinics. Strangely enough, the very first disease that he inoculated produced a clearly defined case of cowpox. What was this disease of the horse? It could not be designated "sore heels," since it was localized in the head, and consisted of small blisters, the size of a pea, upon the mucous membrane of the lips, the lower surface of the tongue, the inner face of the cheeks, and the gums. There was no trace of the eruption except within the mouth.

During the next few months this horse disease, which was capable of generating cowpox, appeared in the clinics of Alfort under all the various forms which it is capable of assuming. At one time localized in the pasterns, as seen by Jenner, at other times affecting the hocks, the general surface of the body, the nose, or the internal surface of the mouth; it at first appeared inexplicable that all of these different manifestations of disease should produce cowpox when inoculated upon the udders of bovine animals. "If I was able to recognize the specific nature of the disease," says Bouley, "it was owing to the course that I had adopted of interrogating by inoculation all the eruptive diseases of the horse that the chances of the clinic brought under my eyes."

When all the evidence from these and other inoculation experiments was brought together, it became plain that what had been regarded as a number of distinct diseases was in reality but one and the same contagion affecting different parts of the horse's body. When this contagion was transferred from animal to animal by the shoer in handling the lower part of the limbs, the eruption was usually confined to the pasterns and fetlocks. When the communication was by means of the currycomb and brush, the pustules were disseminated over the surface of the body, but appeared particularly where the skin was thinnest and the virus most easily introduced, as upon the neck, thighs, and hocks. When the animal contracted the disease by smelling of affected individuals or rubbing its nose against them, the eruption very naturally occurred upon the skin of the lips and nose and upon the mucous membrane of the interior of the nostrils. When the virus was taken into the mouth with contaminated forage, the vesicles appeared upon the mucous membrane of the lips, tongue, and cheeks. And, finally, when the contagion was communicated by the act of copulation, the eruption was seen upon the external organs of generation. To this specific disease, which appeared under so many forms, H. Bouley gave the appropriate name of horsepox.

RELATION OF SMALLPOX, COWPOX, AND HORSEPOX.

Whether the virus of this disease is taken from the horse or cow and inoculated upon a susceptible human being, it produces substantially the same effects—a characteristic vesicle with regular course of development, which confers immunity, more or less complete, from smallpox. This remarkable result has raised the question as to the relation which exists between smallpox, on the one hand, and horsepox and cowpox, on the other. Are these essentially one and the same disease, due to contagion of the same origin, but which has been modified by developing in different animal species for a series of generations? or, are they distinct, different, and incapable of being changed one into the other? There have been many investigations made with a view of settling this question, which have been variously interpreted, but for most pathologists it is probably still held as undecided. The experiments upon animals as well as upon mankind prove that cowpox grants immunity from smallpox and smallpox from cowpox; and it is, therefore, reasonable to conclude that they are closely related, if not identical, in origin. It has, however, been shown to be very difficult, if not impossible, to transform smallpox into cowpox by inoculating the virus upon a series of bovine animals, and in the few cases where it is supposed that this was accomplished there are reasons for doubting the correctness of the conclusion.

EXPERIMENTAL INOCULATIONS UPON ANIMALS AND CHILDREN.

What strikes the student of methods as most conclusive in the history of the development of our knowledge of variola is the prominence of experimental inoculations upon animals and children. The clinical observer had problems presented to him which he was unable to solve by observation alone, and in order to clear up the mysteries and obtain light he was obliged to combine experimentation with observation. There are those, no doubt, who will be horrified by the references to these experiments upon children, but it should be remembered that at that period smallpox was the great destroyer of children; that they were frequently and purposely exposed to it or inoculated with its virus in order that they might have an attack at a favorable time and obtain immunity. Smallpox inoculation, if not as common as the vaccination of the present day, was certainly very largely practiced. Under such circumstances, the inoculation of children with smallpox virus, after they had been vaccinated with cowpox, is no more to be condemned than the general practice of inoculation, which before the discovery of vaccination was so widely adopted and so useful as a prophylactic measure.

CONTAGIOUS PLEURO-PNEUMONIA OF CATTLE.

SPREAD OF PLEURO-PNEUMONIA.

In the early part of the eighteenth century there began to appear accounts of an acute lung disease of cattle, which affected these animals in the mountains of Suabia and Switzerland. This disease very slowly extended to adjacent parts of Germany, Italy, and France, and in 1769 the first really important investigation was made of it in France by Bourgelat, the founder of the veterinary schools, who published an excellent account of his observations. Bourgelat described what he saw—the symptoms, the appearance of the diseased organs, the course of the disease, and its fatal character. He considered that the cause was atmospheric variations, cold and abundant rains, to which the animals were exposed, and sudden passage from warm stables to such rains. There is no evidence that he suspected contagion.

During the wars of Napoleon the disease was considerably spread over Continental Europe, but it was not until the increased traffic and interchange of animals, which dates from about 1820, that its general dissemination occurred. From 1820 to 1840 it extended into most parts of France and Germany. In 1826 Belgium was infected; in 1833 it reached Holland; in 1839 it was carried from Holland to Ireland; in 1841 or 1842 it reached England, and from there was exported to Sweden in 1847. The contagion was brought to the United States with imported cattle in 1843. It was carried to Spain in 1846, to Denmark in 1848, to South Africa in 1854, and to Australia in 1858.

During all of these years there was a constant discussion and contest between the clinical observers as to whether the disease was of spontaneous origin or whether it was due to contagion. Haller, in 1773, expounded the doctrine of contagion with a clearness and force that is surprising, and stated that even in Switzerland, the home of pleuro-pneumonia, this disease does not arise except by contagion. In 1792 Chabert published his "Instruction sur la peripneumonie," in which his great influence was thrown with those who believed in contagion. Nevertheless, from 1800 to 1850 the conclusion that pleuro-pneumonia was not a contagious disease steadily gained adherents. During this long polemic and period of uncertainty, sanitary regulations were neglected, the plague spread to all parts of Europe, and even invaded America. Before the experimental proofs of contagion were generally accepted the disease had been carried to the African and Australian continents, and practically the whole cattle-producing world was infected.

This brief history of the invasion of a large part of the world by one of the most serious and fatal forms of contagion demonstrates again the impossibility of determining such pathological problems by mere observation, and yet we are told by those who oppose experimentation upon living animals that the investigator must not experiment, but must confine himself to clinical observation. Let us see how the question as to the contagiousness of bovine pleuro-pneumonia was finally solved.

INVESTIGATIONS OF PLEURO-PNEUMONIA IN EUROPE.

In 1850 the prevalence of the disease had become so serious that Dumas, then minister of agriculture, commerce, and public works of France, appointed a commission to investigate its nature and cause. This commission at once proceeded to test the contagiousness of pleuro-pneumonia by experimentation. To determine the question as to whether the disease could be communicated from a sick to a well animal, they adopted the plan of introducing sick animals into a stable of healthy ones and noting what followed. The result of this experiment was that 50 per cent of the exposed animals contracted pleuro-pneumonia—15 per cent died and 35 per cent recovered. In addition, 30 per cent of the exposed animals contracted a cough indicative of a very mild form of the disease, while 20 per cent appeared to entirely resist the influence of the contagion. It is this 20 per cent, remarked H. Bouley, which furnished the facts upon which rest the arguments of the noncontagionists.

In Great Britain there was a similar difference of opinion on the subject of contagion, and as late as 1859 an article was published in the Transactions of the Highland Agricultural Society of Scotland, written by Professor Dick, principal of the Edinburgh Veterinary College, in which he tried to prove that pleuro-pneumonia is produced by atmospheric causes, but not by contagion.

A commission appointed in Prussia to investigate the cause and method of transmission of this disease reported in 1852, through Ulrich, that it was certainly contagious.

Notwithstanding this and much other experimental work, there were many in all countries who refused to accept the evidence, and, basing their conclusions upon clinical observation, they insisted that the disease was of spontaneous origin and not due to contagion. This contest over the cause of the disease led to intense opposition to suppressive measures and permitted the continued spread and destructive effects of the contagion. In Australia the contagion might have been stamped out if proper measures had been promptly enforced, but this seems to have been prevented by the obstinacy and active opposition of the noncontagionists. A pleuro-pneumonia commission was appointed to investigate the question of contagion, and while the commission investigated and gathered observations to establish the noncontagiousness of the disease the contagion leaped beyond the possibility of control, and to this day (1899) its ravages unfortunately continue among the herds of that great cattle-producing continent.

The members of the Australian commission were to a man noncontagionists, and they labored with all the strength of a preconceived opinion to prove their side of the controversy. They fetched healthy cows from Tasmania, where pleuro-pneumonia had never been, placed them in stalls beside diseased animals, inoculated them in various crucial ways, and then declared their inability to communicate the fever by contagion. They reported the result to the legislature, and based upon their failure an advice deprecating any further legislative interference. And yet the Government printer's ink was hardly dry upon their report when a counter report came from the butchers of Geelong, who had bought for slaughter the experimental bullocks, that the animals were all diseased, unfit for human food, and demanding back their money.[1]

While the methods of this commission can hardly be taken as a model in all respects for scientific investigations, the evidence finally obtained from their experiments was nevertheless convincing, and, although the critical period when the disease might have been stamped out was allowed to pass without decisive action, the contagiousness of the disease is no longer seriously contested.

INVESTIGATIONS OF PLEURO-PNEUMONIA IN THE UNITED STATES.

In the United States the experience with pleuro-pneumonia was almost parallel with what occurred in Australia. Introduced in the vicinity of New York City in 1843, the disease appears to have been regarded as due to climatic conditions rather than contagion, and was allowed to slumber without attracting much attention until it was investigated by Gamgee in 1868 and 1869. In the meantime an importation of cattle from Holland had carried the disease to Massachusetts in May, 1859. Although the nature of the disease was recognized and brought to the attention of the legislature, the contagion was allowed to spread for a year before authority was granted for its suppression. It was then necessary to slaughter 932 animals to dispose of all that were known to be exposed.

A year later it was found that some affected animals had eluded the commission and that the disease still existed. There now began a most remarkable series of delays, obstructions, and efforts on the part of misguided persons to prevent the eradication of the plague. Commissioners were appointed who did not believe in the existence of a contagious disease. The governor directed that experiments be made

[1] Veterinarian, 1875, p. 681.

to test the question of contagion, and, as so frequently happens where scientific methods are not used, these were unsatisfactory. In 1864 the board of commissioners had again been reorganized and experiments were still in progress to test the contagiousness and curability of the disease. In 1865-66 it was stated that the commissioners had been so far successful that but few cases had occurred during the year. The experiments also seem to have had positive results, as it was reported that of six animals exposed four had certainly contracted the disease. In the report for 1866-67 the commissioners announce the extinction of the disease, the last cases having occurred in October, 1865.

The contagion which was imported at New York was, however, allowed to exist and spread until, in 1879, an effort was made by the States of New York and New Jersey to eradicate it from their territory. At this time the infection existed in Connecticut, New York, New Jersey, Pennsylvania, Maryland, District of Columbia, and Virginia. The efforts of the States were not well sustained and resulted unsuccessfully, though they served to attract attention to the danger which constantly menaced our cattle industry. The realization of this danger led Congress in 1884 to establish the federal Bureau of Animal Industry, the principal object in view being the investigation of the disease and the adoption of measures for its control.

There has been much skepticism expressed by influential persons as to the existence of pleuro-pneumonia in the United States, and doubt as to its contagious character in case the disease were found. Opinions of this nature were so freely declared that the Commissioner of Agriculture deemed it advisable to direct an experiment to be made which would once for all settle these questions. According to his instructions, new stables were erected upon an island easily accessible from the city of New York. There were but fifteen native cattle upon this island, and there was no history of any disease ever having appeared among them. When the stables were completed eighteen cows and thirteen calves were brought direct from Canada, a section where no disease having symptoms at all simulating those of pleuro-pneumonia had been observed, and were placed in the stables erected for this experiment. These animals were thoroughly examined by experts and found to be entirely healthy.

It was believed that by selecting an island where no lung disease of cattle had been known, in building new stables on well-drained land, and in bringing healthy cattle from a country where the disease had never been observed, the conditions of the experiment were such that the results would be absolutely reliable. To expose these animals in such a manner as to test the contagiousness of the malady, five cows selected in the city of Brooklyn as being affected with contagious pleuro-pneumonia were placed in the stable with the healthy Canadian cattle. As a result of this exposure by close association, twenty-two of the thirty-one experimental animals contracted pleuro-pneumonia between September 30, 1884, and January 3, 1885, a period of less than three and one-half months.

This experiment was convincing as to the existence and contagiousness of the disease. Within a comparatively short period 71 per cent of the exposed animals had become affected, and with a number of these the attacks were very acute and typical in symptoms and development, while the appearances of the lungs after the death of the animals were perfectly characteristic.

SUCCESS OF EXPERIMENTAL EXPOSURES AND INOCULATIONS.

This ended the experimentation with pleuro-pneumonia in the United States and furnished an incontestable basis for the rigorous sanitary measures which led to the final eradication of the contagion. What must appear to every reader as remarkable is the doubt as to the contagiousness of the disease which was so tenaciously held in every affected country. It appears as though clinical observation led more people to erroneous conclusions than to correct ones. And where such differences of opinion resulted from observation, how was the truth to be known? In every country the resort was finally to experimental exposures and inoculations, and the results of these have been clear and satisfactory. The measures formulated in harmony with the conclusions drawn from the experiments have been successful in extirpating the disease from the United States, Great Britain, and other countries, and the question of its contagiousness appears forever settled.

There have been numerous other questions that have been investigated, and the effort to discover the active agent of the contagion has been persistent and thorough. It has long been known that the serum, or exudate, of the diseased lung was virulent, and it has been extensively used for inoculation with the purpose of conferring immunity. The microscopic examination of this serum and the attempts to make cultures from it by the ordinary bacteriological methods failed to reveal any microorganism, and it is only recently that apparent success has been obtained by making such cultures in collodion capsules placed in the abdominal cavity of an animal a sufficient time for multiplication to take place. The microorganism obtained was much smaller than any previously discovered and could not be defined with existing powers of the microscope.

ANTHRAX (OR CHARBON).

Accounts have come down to us from the earliest historical times of outbreaks of a plague affecting man and most species of animals which are identified by students of this subject with the disease now known as anthrax, carbuncular fever, malignant pustule, or charbon. Whether the plague described by Homer in the first book of Iliad and the sixth plague of the Egyptians were or were not manifestations of anthrax may be open to some question; but by the beginning of the Christian era the descriptions became so clear that there is no reason to doubt the prevalence of anthrax at that period with substantially the same characteristics as it presents at the present day. During the long period of the middle ages frequent outbreaks are noted, which, with the revival of learning and the increasing attention given to professional studies, were more often mentioned. The eighteenth century is remarkable for the large number of epizootics of this nature which occurred in Europe.

EARLY DESCRIPTIONS OF ANTHRAX.

As might be expected, the diagnosis at that period was far less accurate than to-day, and it is not difficult to perceive that widely different diseases were sometimes confounded under the single term of anthrax. Thus, rinderpest was confused with anthrax during the eighteenth century and as late as the second quarter of the nineteenth, while blackleg, or symptomatic anthrax, and malignant œdema have only been differentiated from it in recent years by bacteriological researches.

Chabert (1782) gave the first systematic description of the disease and pointed out the symptoms which were peculiar to it. He described three forms: (1) Anthrax fever, or internal anthrax, characterized by fever without external swellings; (2) essential anthrax, manifested by external swellings without preceding general symptoms; (3) symptomatic anthrax, characterized by fever followed by external swellings. The dark color of the blood and flesh, together with the severity of the symptoms, and the rapid course and fatal termination, were characters recognized from the earliest antiquity.

INVESTIGATIONS REGARDING THE CAUSE OF ANTHRAX.

As there are numerous and extensive districts where anthrax has been endemic and enzootic from time immemorial, and as it attacks nearly all varieties of animals and is readily contracted by man in caring for diseased animals, skinning carcasses, making post-mortem examinations, eating the infected flesh, handling the skins, or sorting the wool, the great number of cases attracted much attention and led to constant efforts to discover the cause. The various investigators attributed the origin of the disease to about every condition to which the animals could possibly have been exposed. Some taught that it was due to small, badly ventilated, and unsanitary stables; others that it was caused by food of bad quality, forage and grain too recently harvested, or covered with rusts or molds; still others attributed it to the herbage of artificial pastures, clover, lucern, and corn; yet another class found its origin in atmospheric conditions, such as excessive heat and moisture; while, finally, there were those who, rejecting all of these conditions, found what they believed to be the true cause in the conditions of the soil, that is, in the moisture, the clay, and the lime, which were believed to coincide with the areas in which the disease was enzootic.

Renault and Reynal, authors of the article on charbon, in the "Nouveau Dictionnaire de Médecine, de chirurgie et d'hygiene vétérinaires," writing as late as 1857, after recapitulating these various theories, naively admitted that "the causes which give birth to anthrax are still enveloped in a certain obscurity, in spite of the researches of which they have been the object. Perhaps, even, it is true to say that this obscurity results from the large number of these researches and the different points of view of the observers who sought to study this disease. In fact there are almost as many special and different causes which have been assigned to it as there are particular treatises on the subject. It is here, above all, that the old aphorism is true: Quot homines, tot sententiæ [minds as many as the men]."

Nevertheless, from the beginning of the century physicians had observed that certain malignant pustules in man originated by accidental inoculation from animals affected with anthrax, or from their carcasses, and Barthélemy, in 1823, succeeded in producing the disease in horses and sheep by inoculation and feeding with anthrax blood. The following year Leuret communicated the disease by transfusion of blood from a diseased to a healthy horse.

These positive results were explained away by comparing them with the effects which follow inoculation with putrefying animal matters, and the most that was gained was the assumption of the putrid nature of the anthrax virus.

In 1836 Eilert obtained infection in every case by inoculation of blood from sheep to sheep, from sheep to horses, and from cows to sheep. The feeding of clover hay which had been moistened with infectious blood and afterwards dried in the sun killed two sheep out of three.

One of the studies of this disease was made in 1842, under the direction of the French minister of agriculture, by Delafond, an exceedingly able professor of the Alfort veterinary school. There had been for many years an enzootic disease affecting the sheep of La Beauce, province of Eure-et-Loir. This is a district with fertile soil, favorable to animal production, and where sheep are raised and fed in large numbers. There was but one obstacle to the maintenance of this industry in a prosperous condition—the presence of the disease known as sang, coup de sang, maladie de sang, or sang de rate, which destroyed 20 per cent of the animals annually. The first fact observed by Delafond after reaching this section was that the disease most frequently attacked the animals which were youngest, which had been thriving in the highest degree, and which promised to be the best in the flock. Considering this fact in connection with the fertility of the soil, the abundance and the quality of the crops, and the liberality of the feeding, Delafond reached the conclusion that the disease was only a condition of plethora, an excess of blood circulating in the veins, and, above all, a predominance of red globules in this liquid. He analyzed the soil, proving its fertility favorable to the production of forage rich in nutritive principles; he analyzed the blood, showing this to contain a high percentage of albumin, fibrin, and red globules; he analyzed the plant food and found this, as he predicted, having a high nutritive value; he examined the sick animals and the carcasses of the dead ones, finding the distended blood vessels, the thickness of the blood, the frequent hemorrhages, the swollen spleen, the congestion and dark color of the other organs, all apparently uniting to establish his theory that the disease was plethora, caused by too rich and too abundant food. The frequent development of malignant pustules in persons who handled the dead carcasses or their products he explained as due to a septic or anthracoid alteration of the blood, resulting from insufficient ventilation of the stables and the inhalation of putrefactive gases.

H. Bouley afterwards remarked concerning the above report:

Nothing proves better than this document, remarkable for the logic of its deductions, but the premises of which were a fundamental error, how difficult it is to seize and interpret the relations of things when one has no other basis for judgment than that which observation alone can furnish. Delafond had found a part of the truth when he established a relation between the food supply and the aptitude of the sheep to contract the disease. But observation could not conduct him further and give him an accurate notion of this maladie de sang. It was necessary to resort to experimentation, and it was because he did not invoke this method that his researches led him into error, and that he only saw plethora in this disease of La Beauce, the identity of which with anthrax was soon afterwards recognized.

It was but ten years later (1852) that Boutet read before the Academy of Medicine of France a report of an experimental study of this disease of La Beauce. He showed that the disease might be communicated by inoculation, by transfusion of blood, by direct contact, and exceptionally by cohabitation. It was not only communicable to sheep, but to horses, cattle, and rabbits. The sang de rate of the sheep, the sang, or anthrax fever, of cattle, the anthrax fever of the horse, the malignant pustule of man were shown by these inoculation experiments to be one and the same disease. It was also shown that the contagion resided in all the organs and liquids of the body and that it might be inoculated from animal to animal indefinitely without losing its virulence. Here at last was something definite and tangible in regard to this disease, a foundation of fact upon which to build by future researches.

In 1845 and 1846 Gerlach had published papers giving accounts of further experiments proving the contagiousness of anthrax and showing the persistence of the contagion in the soil three years after the burial of carcasses of animals dead of this disease. In 1850 Rayer and Davaine called attention for the first time to the presence in anthrax blood of small filiform bodies, in length about twice the diameter of a blood globule and without spontaneous movements. In 1855 Pollendar stated that he had observed since 1849 the little rods mentioned by Rayer and Davaine, and that they possessed the histochemical reaction of a vegetable substance. He was unable to determine whether there existed any relation between the presence of these bodies and the virulence. These rod-like bodies were again mentioned by Brauell in 1857, who not only observed them in the blood of men and animals which had died of anthrax, but saw them in the blood before death, and concluded that their presence confirmed the diagnosis and warranted the prediction of early death. Brauell did not suspect that these bodies caused the disease, but, on the contrary, was of the opinion that they were transformed after death into the mobile vibrios of putrefaction.

In 1860 these little rods of charbon were studied by Delafond, who confirmed their significance in the diagnosis and prognosis of the disease when they were found in the blood of sick animals. He observed, further, that when the blood containing these bodies was preserved in small glass vessels in contact with the air they developed in the course of four days to two or three times their original length, while preserving about the same diameter. In eight or ten days their length was quadrupled or quintupled. These experiments having satisfactorily demonstrated that the anthrax filaments were an organic vegetable substance, he tried to obtain a complete development of this organism, that is, to make it produce spores or grains. In this he failed, but he concluded it was extremely probable that there circulated some time before death in the blood of animals affected with anthrax, multiplying prodigiously, vegetable filaments which might develop when the blood was drawn from the veins and placed in conditions favorable to vegetation, producing a very remarkable mycelium formed of numerous delicate filaments. He did not dare to decide whether the anthrax rods were the cause or the effect of the disease. Nocard and Leclainche remarked that the sarcasm with which these too advanced views were received is sufficient to explain his timid hesitation.

APPLICATION OF THE GERM THEORY TO ANTHRAX.

The publication in 1859 of Pasteur's memoir on butyric fermentation threw new light upon the development and effects of the micro-organisms, and led Davaine to apply the "germ theory" to anthrax, which he did in papers published during the years 1863 and 1864. This was a great step in advance, as previous to that time there was not only ignorance of the cause of anthrax, but of all contagious diseases. The nature of contagion was the bête noire of the medical profession. It was the one thing that appeared unattainable, either through the reagents of the chemist or the apparatus of the microscopist. There is consequently no need for wonder that when an investigator claimed to have pierced the impenetrable veil that for all time had shrouded this subject, he was met with the most pronounced skepticism and the keenest criticism.

For thirteen years the discussion continued without much progress either against or in favor of the new theory. New facts were produced, some of which apparently had a bearing in one direction and some in the other. Davaine's conclusion was still but a hypothesis or conjecture without positive evidence to sustain it. This was the condition of the subject when Koch published his remarkably able paper on the subject in 1876. He began by a study of the biology of the anthrax rods, finding that in the liquids of living animals they multiplied rapidly by lengthening and dividing, and that although he inoculated them from mouse to mouse for twenty consecutive times, no other forms were produced. In the blood and juices of dead animals or other favorable nutritive liquids, with admission of air and between certain extremes of temperature, they grew into extraordinarily long threads, with the formation of numerous spores. These spores, placed in a suitable liquid under favorable conditions, germinate and produce again the bacillus threads.

The bacillus threads or filaments are delicate and easily destroyed. A few days in an unfavorable temperature, a similar period deprived of air, diluting the fluid containing them with a large quantity of water, or drying the substances containing them was sufficient to destroy their vitality. On the other hand, the spores are very resistant, and when once formed are capable of existence under the most unfavorable conditions. These facts furnished the clew by which Koch was able to demonstrate the agency of this particular organism in causing the disease known as anthrax.

When fresh anthrax blood was preserved without contact with the air till the filaments died, the fluid at once lost the power of communicating the disease, as shown by inoculation experiments. On the other hand, with the admission of air under otherwise identical conditions, the organism grew, formed spores, and the liquid retained its virulence indefinitely. Again, by admitting air, but by keeping the fluid in a temperature of 8° R., which prevented the formation of spores before the rods died, the virulence was again lost. So by drying rapidly or by diluting with much water the death of the bacilli resulted and the activity of the liquid disappeared. Koch further showed that when spores had once formed, neither cold, nor deprivation of oxygen, nor drying, nor dilution with water any longer destroyed the virulence of the anthrax liquids.

Here was a scientific demonstration of the identity of this microorganism with the active principle of the infectious liquids. It showed that while the bacillus or its spores retained vitality the contagion existed, and when the bacillus lost its vitality without forming spores the contagion disappeared. The connection between the bacillus and the contagion was established beyond reasonable doubt.

The publication of these facts placed the germ theory of contagion upon a solid foundation which neither the storms of criticism nor the earthquakes of negative evidence have been able to destroy.

The first objection raised to this theory was that when the blood first becomes virulent no bacilli can be discovered by the most careful microscopical examinations; if the bacilli were the cause of the disease they should be apparent as soon as the blood is capable of communicating it by inoculation. Pasteur explained this fact as due to the difficulty of discovering one or two bacilli in such a large surface as is made by a drop of blood under the higher-power lenses. For instance, a drop of blood pressed flat between the object glass and thin cover presents a surface of one-half inch in diameter; this magnified only 500 diameters gives a surface with a diameter of 20 feet. And this is sufficient to fill the field of vision nearly 1,800 times. The accuracy of this explanation was proved with culture experiments, by showing that whenever the blood was virulent a drop of this blood added to a suitable culture liquid would produce an abundant growth of the bacillus.

The distinguished investigator, Paul Bert, took up the subject, and read a paper before the Académie des Sciences, in which he showed that compressed oxygen, which was supposed to kill all living things, did not destroy the anthrax virus, and that blood treated with it would still yield an alcoholic extract capable of producing anthrax. Now, absolute alcohol, as well as compressed oxygen, had been supposed to be fatal to all life. If, then, the virus survived both the action of compressed oxygen and solution in alcohol, he reasoned it was because it was not a living organism, but a chemical agent allied, perhaps, to diastase.

Once more the genius of Pasteur was equal to the occasion, and he demonstrated, to the satisfaction of Bert, that although the bacilli were destroyed by the agents he had used, their spores were not. He subjected Bert's alcoholic extract to microscopic examination and proved the presence of large numbers of these spores. Bert afterwards found that such spores preserved for five months in ordinary alcohol were as virulent as at first.

THE GERM THEORY ESTABLISHED.

The great contest over the germ theory of disease was settled by the experiments reported in 1876 and 1877, and the way was open to apply this great discovery to practical medicine. What a revolution in medical thought and practice has resulted can only be appreciated by comparing the text of medical works of twenty-five years ago with that of the present day. There were some individuals, however, who could not understand the difference between positive and negative evidence, and who did not for years fully grasp the fact that the germ theory was established. These persons continued to raise objections, and some of them are still telling us that investigators have gone mad over bacteriological studies and that the whole structure which they have raised during the last quarter of this century is doomed to crumble and disappear. Such objectors can have little effect upon the progress of science at this day, since every student has learned that a fact once established by positive evidence is as solid as the mountains and endures for all time; yet, many will die without accepting the germ theory, just as numerous contemporaries of Harvey died disbelieving in the circulation of the blood, but the recorded facts and the demonstrations of the germ theory will stand, as Harvey's discovery has stood, and it is as fruitless to inveigh against them as to attempt to sweep back the rising tide with a broom.

Many practical results in the treatment of anthrax outbreaks have followed the discovery that it is caused by a particular microscopic organism which we now know as the *Bacillus anthracis*. It has been recognized that this bacillus may multiply in the soil and in stagnant water; that its spores may retain their vitality and virulence after remaining in the earth for many years; that these spores form in the carcasses of dead animals and are brought to the surface from the pits where such carcasses are buried through the agency of earthworms; that disinfection, as it was practiced previous to 1876, was ineffectual in destroying the spores of this microbe, and that more active agents were required; that the essential condition which keeps up the disease is not the character of the soil, not the condition of the atmosphere, not the defects of the stable, but the presence of the bacillus in the soil of the pastures and upon the forage gathered from infected fields; and, finally, that the bacillus may be attenuated and form a vaccine which will in most cases grant immunity and protect animals from the infection. The use of this vaccine is increasing, and has reduced the mortality in the infected districts from an average of 10 per cent with sheep to less than 1 per cent, and from 5 per cent with cattle to less than one-half of 1 per cent.

BLACKLEG (SYMPTOMATIC ANTHRAX).

This disease, which is characterized by a rapidly developing swelling, with the abundant formation of gas in the tissues of the affected part, is seen principally in cattle, and until recent years was supposed to be identical in cause and nature with anthrax fever. The swelling appears most frequently in the upper part of the limbs, and when cut into is found filled with blood and very dark in color; hence, the name blackleg, by which it is commonly known in the United States. It is a common disease and almost invariably fatal.

DESCRIPTIONS OF BLACKLEG FROM OBSERVATIONS.

When Chabert wrote his classical description of anthrax in 1782, as we have already seen, he divided it into three clinical forms: (1) Anthrax fever, or internal anthrax; (2) essential anthrax, manifested by external swellings without preceding symptoms of fever; (3) symptomatic anthrax, beginning with fever and soon followed by external swellings. In the first division there could only be included cases of true anthrax, but in the second and third divisions there were brought together those forms of anthrax in which the virus penetrated the skin or mucous membrane and formed a visible swelling at the point of entrance, and also the swellings due to the contagion of an entirely distinct disease now known as blackleg, or symptomatic anthrax.

In general, the anthrax swellings precede the fever, while with blackleg the swellings frequently precede and often follow the fever. Chabert's classification, while a great advance from the ideas of his predecessors, was in this respect artificial and inaccurate, but was nevertheless the accepted interpretation of the facts for nearly a century.

There was little advance in the knowledge of this subject until 1856, when Walraff described an emphysematous form of anthrax, thus calling attention to the essential difference between the clinical symptoms of the anthrax and blackleg tumors, but he apparently did not suspect that they were distinct diseases. Bollinger in 1873 and Feser in 1875 pointed out marked differences, and Schindler and Weber in 1876 again called attention to the disease characterized by these emphysematous, or gaseous, tumors, and expressed their opinion that it should be differentiated from anthrax, since no case of its transmission to man had been observed, although the skins of affected animals were utilized, and the flesh even was consumed by the inhabitants of the infected districts in the Alps.

These opinions were not generally accepted, or at the best were regarded as of the nature of conjectures rather than demonstrations.

The divergent views expressed by different authorities and the apparent inconsistency of the observations served to increase the confusion rather than to bring order and light into the controversy. It had been observed that anthrax fever was often communicated to the men who handled the carcasses or skins of animals which had died of the disease, and that such accidents never occurred from the emphysematous tumors of symptomatic anthrax. In attempting to learn the reason for the transmission in one case and apparent noncontagiousness in the other, when both were regarded as essentially the same disease, inoculation experiments were made which showed that anthrax fever was regularly communicated from animal to animal by inoculation with the blood of an affected animal, while the blood of animals affected with symptomatic anthrax was not virulent, and material from the diseased tissues failed to communicate the disease in the great majority of cases. Did these facts indicate that two distinct and separate diseases existed where but one had previously been recognized? or, did they simply mean that in anthrax fever the disease was generalized and the contagion circulating throughout the body, while in symptomatic anthrax the contagion was localized in the swelling, which was the principal symptom of the morbid condition, and that it was here modified by septic complications?

THE NATURE OF ANTHRAX DEMONSTRATED BY EXPERIMENTS.

This question could not be answered by observation alone, nor were those who attacked it by experimentation able to solve the difficulties until the inspiration which followed from the investigations of Koch and Pasteur pointed the way. The demonstration that the *Bacillus anthracis* is the cause of anthrax fever, the clear description of its form and biological characters which enabled the investigator to identify it with certainty, and the methods of cultivating and studying bacteria introduced at this period made it possible for Arloing, Cornevin, and Thomas to carry out the brilliant series of experiments which demonstrated that anthrax fever and symptomatic anthrax were entirely different and distinct diseases.

These investigators published their first paper in 1879, three years after Koch had shown that anthrax fever was caused by the *Bacillus anthracis*, and when it was well known that the bacillus was easily found in the blood and tissues of animals which had died of that disease. They announced that careful microscopic examination and cultures, according to Pasteur's method, failed to reveal the *Bacillus anthracis* in the tumors or in the blood of animals affected with blackleg either before or after death. They also made thirty-four inoculations, using three young cattle, three sheep, two horses, and twenty-six rabbits and mice. All of these failed to communicate the disease. They therefore concluded that neither the blood nor the liquids of the tumors or affected lymphatic glands, in cases of symptomatic anthrax, contained either the *Bacillus anthracis* or its spores.

In later communications it was shown that blackleg is inoculable from animal to animal, and that the failures of the earlier inoculation experiments were partly due to the use of insusceptible animals. Cattle, sheep, goats, and guinea pigs readily contract the disease. Horses, swine, dogs, cats, rabbits, and fowls are either immune or have a great power of resistance toward this virus. Even cattle, the species in which this malady develops most frequently under natural conditions, are not susceptible at all ages. Calves under three months old and cattle over four years were found to have a high resisting power.

It was also necessary to determine experimentally the parts of the body in which the virus existed in most concentrated form. The blood is not virulent until just before death, and then, like the serum from the tissues surrounding the tumors, often fails to communicate the disease. The liquid of greatest virulence is obtained from the most discolored and darkest parts of the tumor, though the bile and amniotic liquid are both quite active. Further, it was found that a certain dose of virus must be used, and that this should be inserted into favorable portions of the body in order to obtain uniform results.

Microscopic study of the virulent liquids revealed the constant presence of a rod-shaped microorganism, which is endowed with power of active motion and having in many cases a spore at one end. The first attempts to cultivate this germ were not successful. It would not multiply in the presence of oxygen, as it belonged to that class of organisms known as anaerobic, and it required liquids of special composition to favor its growth. These difficulties overcome, it was found that the bacillus could be grown through many generations and retain its virulence indefinitely with proper conditions of environment.

BLACKLEG AND ANTHRAX COMPARED.

The bacillus of blackleg differs remarkably in some respects from that of anthrax. While the former is anaerobic and forms spores within the body of the living animal, the latter is aerobic and can only form spores after it has come in contact with the air. These peculiarities in the microbes explain the remarkable differences in the resisting powers of the two forms of virus under varying conditions. The spore being the resting stage of the bacillus and the form in which it is most resistant to unfavorable conditions, it is clear that, if this microorganism is the true cause of the virulence, the virus should retain its active properties longer and be more difficult of destruction when it contains spores than when rods alone exist. This is exactly what was found to be the case, and it explains why a disinfectant which will destroy the contagion at one time will not do so at another.

The contagion in fresh anthrax liquids, as they contain no spores, is destroyed in a few minutes by a temperature of 58° C., while fresh blackleg virus, always containing spores, requires a temperature of 100° C. for twenty minutes to produce the same effect. And on account of this ever-present spore the blackleg virus more surely resists the influence of putrefaction and other unfavorable conditions, and is therefore one of the most difficult to eradicate of all the known forms of contagion.

Comparing anthrax and blackleg experimentally, it was found that the former was easily communicated by scarifications or pricking the skin with a lancet charged with the virus, while the latter was only exceptionally transmitted in this manner. When inoculated into the connective tissue the local lesion produced by anthrax virus in most cases consisted of a small inflammatory area, with slight accompanying œdema, while blackleg virus similarly inoculated caused an enormous swelling, with abundant œdema. Again, the inoculation with anthrax virus into the veins is more dangerous than when inserted into the connective tissue, and is fatal with infinitesimal doses. On the contrary, blackleg virus may be inoculated into the veins in much larger doses than into the connective tissue without producing fatal effects. It was shown that one attack of either of these diseases granted immunity from that particular contagion, but that an attack of anthrax did not protect from blackleg nor did an attack of blackleg protect from anthrax.

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The above experimental studies consequently established the fact beyond controversy that two distinct diseases had previously been grouped together; that the germs of these two diseases were distinct and very different in their biological characters, and that different measures were required for their control.

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This great practical triumph in the control of an infectious disease is due entirely to the application of the experimental method. Without experiments upon living animals and confined to clinical observation, it was impossible to determine whether anthrax and blackleg were essentially identical in nature or whether they were distinct diseases, and much less was it possible to isolate and identify the germ or so to change the activity of this organism as to transform it from one of the most deadly organisms to a harmless protective vaccine.

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In 1814 we find the first known accounts of a disease being disseminated by apparently healthy cattle from certain districts in the Southern States when these cattle were driven North to market. Attention was at that time called to this phenomenon by Dr. James Mease in a lecture before the Philadelphia Society for Promoting Agriculture, who stated that the cattle from a certain district in South

Carolina so certainly diseased all others with which they mixed in their progress to the North that they were prohibited by the people of Virginia from passing through the State; that these cattle affected others while they themselves were in perfect health, and that cattle from Europe or the interior taken to the vicinity of the sea were attacked by a disease that generally proved fatal. In a paper read before the same society in 1825 he says: "The circumstance of cattle from a certain district in South Carolina affecting others with this disease has long been known."

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Many similar outbreaks occurred in North Carolina, Virginia, and Maryland in the first half of the century, but the accounts of them are too meager to be of use. Legislation was enacted in North Carolina, however, as early as 1837 to prevent the driving of cattle into that State from either South Carolina or Georgia between the first day of April and the first day of November; also, to prevent cattle from being driven from those parts of North Carolina, where the soil is sandy and the natural production or growth of timber is the long-leafed pine, into or through any of the highland parts of the State, where the soil or growth of timber is of a different kind, between the dates already mentioned.

Very little more was heard of this disease until about 1850, when cattle bred in Texas began to be driven through Arkansas, Missouri, and Kansas for distribution to feeders in those and other Western States. A mysterious and highly fatal disease then appeared along the great roads, highways, or trails over which these cattle were driven, destroying about 50 per cent of all the native cattle. Persons living near the fording places lost as high as 90 per cent. It was two years before the origin of this disease was traced to the Southern cattle.

From 1856 to 1860 many Texas cattle were driven into the States of Kansas, Missouri, Kentucky, Iowa, and Illinois, and it was stated that the native stock in the sections to which they were taken were swept away by a "dry murrain." An epizootic under such circumstances was so unexpected and contrary to all previous experience that at first the source of the disease was not suspected, and when the Southern cattle were accused there were many who looked upon their presence as a mere coincidence. However, by 1861 the conviction that Texas cattle disseminated disease became so strong that laws were enacted by the States of Kansas, Missouri, Kentucky, and Illinois regulating the movements of Southern cattle.

The disease ceased in these States during the civil war and its ravages had apparently been forgotten, when it reappeared during 1866, 1867, and 1868 with the first droves of cattle from Texas. There was little attention given to it at first, as the number of cattle driven in 1866 and 1867 appears not to have been very large. In 1868, however, the markets and other conditions were more encouraging to those who handled this class of stock, and large herds of Texas cattle were sold for feeding in Illinois, Indiana, Ohio, Pennsylvania, New York, and other Northern States.

As the hot weather of summer came on the disease broke out whereever the Southern cattle had been taken. Of 320 head of native stock shipped from one farm to the East for slaughter, 224 died before they reached their destination, and the remainder were said to have been sent to the rendering tanks. At the little town of Tolono, Ill., from 15,000 to 18,000 Texan cattle were landed. The fever commenced its destructive work about July 20, sweeping away nearly every native animal of the bovine race in that section. Nine hundred and twenty-six head of cattle died in that township, which polled but a trifle over 200 votes, and 5,000 head succumbed in the county. Within 2 miles of the Chicago stock yards, according to the report of the medical officer of the city, but 1 cow escaped, 161 animals having perished. In the vicinity of Loda, Ill., it was estimated that not less than 1,800 cattle died. In Warren County, Ind., the losses reached about 1,500 head; in Jasper County, 400 head; in Marion County, 100 head.

These losses are simply examples of what was occurring in many parts of the Northern States. The disease was soon traced to the Southern cattle, and in the absence of specific knowledge concerning its character there was great alarm as to the extent to which it might spread and its effect upon the public health. While the direct loss from the disease was very heavy and brought disaster to many individuals, the contagion was fortunately one which did not spread from the sick native cattle, and was consequently self-limited. It was also a disease that is not communicable to the human species, and hence did not appreciably affect the public health.

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The excitement and interest aroused by the outbreak of 1868 led to extensive investigations by the Department of Agriculture and by the boards of health of Chicago and New York. These researches were sufficient to establish the symptoms, the post-mortem lesions, and some of the peculiarities in regard to the transmission of the disease. It was shown that there was intense fever, with a temperature ranging from 105° to 110° F., accompanied by great weakness and prostration. The ears and head drooped, the hind legs were advanced under the body, and the fetlocks were partially flexed, constituting, when taken together, a more or less characteristic attitude. The urine, at first tinged with red, became deeper colored, until it had the appearance of undiluted venous blood. On post-mortem examination the liver and spleen were found to be the organs most seriously affected. Both were congested and enlarged. In the liver there was bile-stasis in the ultimate biliary canaliculi, which were found distended and occluded, while the spleen was greatly engorged with blood, and its interior was transformed into a dark semifluid mass. The kidneys, also congested, presented numerous blood extravasations in the pelvic portion.

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Strange to say, the pastures did not always become dangerous immediately after the Texas cattle had traveled over them. In some cases it was observed that susceptible cattle had fed upon such pastures for a month or more after the Texas cattle had left them, and had then been removed to other fields without sustaining any injury, while other Northern animals of the same lot allowed to remain a few weeks longer suddenly developed the disease in a most violent form. How different from the phenomena of other contagious diseases were these manifestations! and how inexplicable in the light of the medical knowledge of that day! Of what did this contagion consist that it could be propagated by well animals and not by those affected with the disease; that it could remain upon pastures inactive and resist sun and rains for weeks and then suddenly attack in the most virulent form all Northern animals that so much as walked across them, while it respected the animals from the South? Surely they were justified who called this a "romance in pathology," since these phenomena were without precedent and to the most enlightened appeared incredible.

These investigations of 1868 and 1869 established the more apparent characteristics of the disease, though for sixteen years afterwards there were scientific men who tried to prove that no such disease existed. During all this time the cattle driven from Texas and Indian Territory to the Northwestern States and Territories for grazing left a deadly trail behind them, which was destructive to the native cattle that crossed it. The stock yards and stock cars became more and more infected, and cattle purchased in the public markets and taken back to the farms for feeding were in so many instances found to have contracted the disease that purchasers avoided such places as much as possible. Even our export cattle that were given the greatest care en route became infected, and as many as two or three hundred would sicken on a single ship. This brought American cattle into disrepute and threatened to lead to annoying restrictions or even prohibition by foreign governments.

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The people of the South said: "What right have you to put restrictions upon our cattle when they are going to market? There is no disease among our cattle; and if the Northern cattle sicken and die, the loss should not be charged against our healthy cattle, the presence of which in certain cases was probably a mere coincidence." These arguments were difficult to meet, doubly so when the cases went to the courts, and it became necessary to explain the part played by the Southern cattle in originating the disease. Here, as in many other cases, observation of the outbreaks which developed spontaneously failed to reveal the mysteries, and it was necessary to question and cross-question nature through experiments in order to obtain the information which she withheld from the ordinary observer.

CONJECTURES AS TO MANNER OF DISSEMINATION OF TEXAS FEVER.

There were numerous conjectures as to the manner in which the contagion was disseminated. Some thought that in driving the Southern cattle such long distances their feet became worn, sore, and ulcerated, and that the discharge from these ulcerated surfaces poisoned the grass and developed contagion. It was believed that this hypothesis was confirmed by the known fact that the Southern cattle apparently lost the power to transmit the disease after they had been upon the Northern ranges sixty to ninety days. Another conjecture was that the contagion resided in the saliva and was distributed over the grass while the infectious animals were grazing. It was also contended by some that the Texas cattle became infectious by drinking from pools of stagnant water, particularly that which contained alkali, and that the infection was distributed with the urine and excrement. Still another conjecture was that the ticks, with which most of the Southern cattle were covered, passed from these to the Northern animals, and the latter, not being accustomed to their bites, became affected with and died from the irritation and fever thus induced. A modified form of this hypothesis was also held, to the effect that the ticks dropped from the Southern cattle laid their eggs in the grass; that myriads of young ticks hatched, covered the herbage, and were taken into the stomachs of the cattle with the food, causing inflammation of the digestive organs, fever, and death.

How were we to decide which, if any, among these divergent views was the correct one? The writer was asked to make a hasty examination of the subject and prepare a preliminary report for publication. This he did, and it is at least instructive as to methods to read his views concerning the part played by the ticks in the transmission of the contagion. The following appeared to be extremely good arguments at the time the report was written (1880):

The tick theory.—One of the most widely spread opinions in regard to the causation of Southern fever is the pathogenic influence of the ticks with which Southern cattle are generally covered and which migrate in large numbers to the bodies of other cattle with which they mix. But the acceptance of this view is simply an evidence of the desire of the human mind to explain the origin of mysterious phenomena. The same principle is exhibited in the popular views regarding the pathogenic nature of *hollow horn*, *hollow tail*, *wolf teeth*, *black teeth*, *hooks*, *etc.*, none of which have the least foundation in fact or reason. The tick theory scarcely explains a single one of the many peculiar phenomena of the disease. Ticks are found everywhere, but are simply more numerous at the South. Their attacks are not confined to the latter half of the summer, nor would they be likely to remain on a pasture from spring till August without doing harm and then suddenly cause an outbreak of the disease. Again, the post-mortem examination plainly indicates the cause of the disease to be an agent taken into the circulation and causing the most important changes in the composition of the blood.

Alas, for the limitations of human observation and reasoning when we fail to establish our premises by rigid experimentation! It has since been shown by experiments, outlined by the writer and carried out successfully by his direction, that the ticks do transmit the contagion of Texas fever, and that all of the mysteries connected with this transmission are explained by an accurate knowledge of the biology of the particular tick involved (*Boophilus bovis*), and of the other parasite (*Pyrosoma bigeminum*), which cooperates to produce the pathogenic effect.

EXPERIMENTS TO DETERMINE THE CAUSE AND DISSEMINATION OF TEXAS FEVER.

The first step toward revealing the nature of the disease was evidently to determine if it could be inoculated from animal to animal. If this question were decided in the affirmative, it would be possible, by continuing the inoculation experiments, to determine how widely the virus was distributed through the body, and with what secretions or excretions it was disseminated by the affected animal. It might also be possible to identify a microorganism as the essential cause and to study its biology.

With these purposes in view, the writer, in 1879 and 1880, inoculated six head of cattle and drenched three with liquids that appeared most likely to contain the contagion. Two of these animals had an attack of fever, one being so seriously affected that it became quite weak and emaciated. In 1882 three more animals were inoculated, one of which became sick in ten days and died three days later of acute Texas fever. This was the first demonstration of the inoculability of the disease, and it proved that a mixture of blood and splenic pulp contained the contagion.

In 1886 Dr. Smith, in studying microscopic preparations from the spleen of an animal that had died of the disease, observed peculiar bodies in the red corpuscles which were suggestive of parasitic micro-organisms. In 1888 and 1889 further studies of these bodies were made, which led to the conclusion that they were protozoa. As the most prominent feature of the disease was found to be a breaking down and destruction of the red corpuscles, and as these parasites existed almost exclusively in the red corpuscles of the blood, there was some reason to think they might be the cause of the disease.

At this period, having completed the survey of the permanently infected district, the writer observed that this district corresponded almost exactly with the habitat of the tick (*Boophilus bovis*), which was almost invariably found to infest the cattle that were capable of transmitting the disease. Taking this coincidence, with the strong belief held by many cattle men of experience, that the ticks had something to do with the production of the disease, it was determined to have this aspect of the question fully investigated. Dr. F. L. Kilborne, who was at that time in charge of the Bureau experiment station, was consulted and given explicit instructions to carry through one or more series of experiments with this object in view. The first experiments were made in 1889, and the result was: (1) That Northern cattle pastured in a field with cattle from the infected district which were infested with ticks contracted Texas fever; (2) that Northern cattle pastured in a field with cattle from the infected district that were carefully freed from all ticks by hand picking did not contract Texas fever; (3) that Northern cattle pastured in a field where no cattle from the infected district had been, but over which had been scattered a large number of ticks, contracted Texas fever.

The result of these experiments was a distinct and positive advance in our knowledge of the disease. It was now known (1) that the disease was inoculable; (2) that the blood of diseased animals contained a microscopic protozoan parasite; (3) that ticks picked from Southern cattle and spread upon pastures were a means of communicating the infection.

It was next important to learn in what manner the ticks conveyed the contagion. From a medical point of view the most plausible theory was that the biting parts of the ticks became soiled with the blood of the Southern cattle, and that these contaminated ticks, migrating to susceptible cattle, carried the virus and inserted it when they began sucking blood from the latter. A study of the life history of the tick showed, however, that this theory was not consistent with the facts. The ticks do not leave one animal and go to another. When they are once upon an animal they remain there until they become mature, and then they drop off, lay their eggs on the surface of the ground, and die. There is no opportunity for this parasite to carry blood directly from the Southern to the Northern animal and inoculate it.

Another hypothesis was that with the blood sucked from Southern cattle the tick took into its body the virus of the disease, and that when the mother tick died and became disintegrated upon the pastures the contagion was liberated and the grounds infected. This supposition was entirely demolished by experiments, which proved that the disease was caused by young ticks hatched from the eggs of the mature ticks which developed upon the Southern cattle, that is, the contagion is in some manner transmitted from the adult tick through its egg to its progeny, and this progeny has the power of inserting the contagion into the circulation of the cattle upon which it happens to fasten itself.

These facts threw much light upon the propagation of the malady, but they were not sufficient to establish a scientific theory explaining the transmission. Indeed, it was yet to be proved that the Southern cattle carried the protozoa in their blood. Microscopic examination was not sufficient to decide the question. A few minute points were observed in the red corpuscles of Southern cattle, but these points were much smaller and far less numerous than the protozoa in sick Northern cattle. The Southern cattle, besides, were in good health, and it seemed improbable that they harbored so deadly a parasite.

There was but one way to decide as to whether Southern cattle carried this contagion in their blood, and that was to inoculate susceptible Northern cattle with the blood of Southern cattle. This experiment was made, and it demonstrated that a comparatively small quantity of blood from a Southern cow, injected under the skin or into the veins of Northern cattle, produced an acute attack of Texas fever. In Northern cattle infected in this manner the protozoa appeared in the blood corpuscles with the same characteristics as when the infection occurred through the medium of ticks. There could no longer be any doubt that the blood of cattle from the infected district contained the contagion of Texas fever.

It was now important to decide how long Southern cattle carried this contagion in their blood after leaving the infected district. Again, it was necessary to resort to inoculation, as the microscope was powerless to decide. The first experiments had been made with the blood of cattle immediately after they had been brought from the South. In the next experiment blood was used from an animal that had been away from the infected district seventy-four days. This also produced disease. In succeeding years experiments were made by inoculating with the blood of cattle that had been under observation, with no chance for reinfection, for one year, two years, three years, four years, five years, six years, and seven years, and in every case the disease was produced. It was concluded, therefore, that this contagion once introduced into the blood of cattle remained there in an active condition throughout the animal's life.

THE PRINCIPAL FEATURES OF TEXAS FEVER.

We were now in a position to understand and explain the principal features of this disease, that is, it was plain that cattle in the infected district carried in their blood the contagion of Texas fever; that this contagion was in reality a protozoan organism called the *Pyrosoma bigeminum*, analogous to the parasite of human malaria; that this parasite was transferred to susceptible cattle outside of the infected district by the Southern cattle tick *Boophilus bovis;* that Southern cattle, although carrying the contagion, were harmless unless infested by this particular tick; that the Southern cattle carried this contagion in their blood for years after leaving the infected district, and would again be dangerous to other cattle if by any chance they were reinfested with the proper species of ticks. A study of the biology of the tick showed that the time required for the eggs to hatch depends upon the atmospheric temperature, and that all the mysteries of the propagation and incubation of the disease depended upon the hatching of these eggs.

THE PROGRESS MADE IN THE CONTROL OF TEXAS FEVER.

The above is a remarkable chapter in the progress of medical science, and has already led to extensive studies of the part played by insects in the propagation of human diseases, and particularly the malarial fevers. That it has opened up a new field of medical research is unquestionable. What has it accomplished toward the control and eradication of Texas fever? In the first place, it has given us a ready method of identifying infectious cattle found in the channels of commerce. Previous to these investigations it was often impossible to tell whether a given carload of cattle unloaded at any stock yards was from the infected or noninfected district. The point from which it was billed was no criterion, since it was common to rebill cars, often for the express purpose of deceiving the inspectors. These great centers of cattle traffic were, consequently, continually infected. To-day, if cattle are infested with the *Boophilus bovis* ticks, they are sent without question to the quarantine yards.

Another line in which progress has been made is in lessening the area of the infected district. Whole counties have been placed above the cattle quarantine line, because the ticks have been destroyed in those counties and the danger of contagion removed. In many other counties the citizens have taken up the task of tick killing and are making rapid progress in freeing their districts from this pest. The infected district, instead of advancing and enlarging in area, as before these investigations, is now diminishing. This work is of immense advantage to the people of the districts involved.

Great success has also been achieved in immunizing cattle taken to the infected district for improving the stock. In the past the greater part of the cattle taken to the infected district died of Texas fever. These losses were 80, 90, and even 95 per cent of the animals introduced. Still, it was so important to grade up the cattle in the vast herds of the South and Southwest that the people of those sections persisted and accomplished much even under such discouraging circumstances. In pursuing the inoculation experiments it was learned that young animals, particularly calves, were much less severely affected than old ones, even with the same dose of virulent blood; also, that as cold weather approached a milder form of disease was produced in the same class of animals. Putting these two facts together, it was decided to immunize some young cattle and test their resistance in the infected district. This was successfully accomplished, and proved that young stock inoculated in the late fall or early winter with virulent blood contracted a mild form of disease, from which the experimental animals recovered, and that these animals sent to the infected district the following spring were but slightly affected with the disease, although untreated animals sent with them either died or were very severely affected and barely survived.

This method of immunizing has now been adopted in practice and is proving very satisfactory. Instead of a loss of 90 per cent among breeding stock taken South, it has been shown that more than 90 per cent can be saved. This means rapid improvement of Southern herds and a vast increase in the value of the animals produced.

There is one other problem under experimentation, which, if it can be solved, will remove the last terrors of Texas fever. That problem is the rapid and inexpensive destruction of the ticks upon cattle from the infected district. Such cattle are now dangerous because of these ticks. They are not allowed to go North, except for slaughter, during ten months of the year. They are always regarded with suspicion, quarantined, and sold as quarantine cattle at a reduced price. This is a constant hardship to the people of a great section of the country; but destroy all the ticks and the cattle are harmless and can go anywhere, for any purpose, at any season of the year. The plan of destroying the ticks is to drive the cattle through a vat containing some liquid that will be fatal to the ticks without injuring the cattle. While it has proved a difficult task to find a liquid that will answer these conditions, there are some which are so nearly satisfactory as to inspire hopes that success in this line will in the near future be achieved.

Confining our argument to the facts which have already been demonstrated, Have we not abundant justification for the experimental method? With a disease so obscure and complex, depending upon two different parasites for its dissemination, one of these so small as to tax the highest powers of the microscope, it was impossible for observation, unaided by experimentation, to solve the mysteries and elucidate it. But the experimental method was invoked, and, as in many other fields of biology, has brought order out of chaos, giving an intelligent comprehension and control of phenomena, where before were only ignorance and helplessness.

PROGRESS IN ECONOMIC ENTOMOLOGY IN THE UNITED STATES.

By L. O. Howard, Ph. D.
Entomologist.

INTRODUCTION.

At the beginning of the present century the United States, with its population of only 5,000,000, with its restricted geographical area, with its small fields and its comparatively slight diversity of crops, and with its infrequent communication and limited commercial relations with other countries, suffered comparatively little from the attacks of insects on its crops. There are old last-century records of the local destruction of the grain crops by the army worm, and as early as 1793 the cotton caterpillar did a great deal of damage to the cotton crop of Georgia and South Carolina. Similar outbreaks occurred in 1800 and 1804, while the Hessian fly,[1] as its name suggests, made its destructive appearance soon after the close of the war of the Revolution.

With the rapid growth of the new Republic, both in geographic area and in population, and with its marvelous agricultural development, many native plant-eating insects, finding in cultivated crops an almost unlimited abundance of food greatly to their taste, multiplied rapidly and became important factors in crop production. As commercial relations with Europe and other countries increased and as the introduction of steam made international journeys more and more rapid, new injurious insects were introduced from abroad, many of them becoming readily established and assuming an importance as crop enemies surpassing that of native species. Many of them, in fact, as has frequently been pointed out, became, for reasons which need not be discussed here and which are not well understood, more prolific and injurious than in their native homes. For a long time these imported species, beginning their work on the Atlantic seaboard, traveled westward by natural spread, entering new regions after a few years, following in the track of the pioneers. Comparatively few have entered our territory from the South, but with the development of agriculture

[1] The "Hessian fly" is a name which well illustrates a tendency to apply as a popular term to an injurious insect the cognomen of a disliked or hated class or individual. Other examples are the use of the name "Abe Lincoln bug" in Georgia after the close of the civil war for the harlequin cabbage bug, which at that time had just reached that State on its northeastward march; the later application of the term "Third Party bug" to the same insect in Texas, and the term "French weed" to the stink weed in portions of Canada of anti-Gallic sympathies.

upon the Pacific coast and with increasing commercial relations with countries beyond the Pacific, injurious insects have at last begun to reach us from a westward direction. From this it will be seen that as the century has grown older the need of remedies against insects has grown greater. Fortunately in this case, the supply of remedies has commensurately satisfied the demand, and the nation has not failed in this direction to justify its claim to be called "a practical people."

SOME OF THE WORKERS AND CAUSES OF PROGRESS.

FIRST NATIVE SCIENTIFIC ENTOMOLOGIST.

William Dandridge Peck, who commenced to write in 1795, was our first native scientific entomologist, and he was as well our first economic worker in this line. The first economic publication of value was probably his "Description and history of the cankerworm," originally printed in the Massachusetts Magazine for 1795, and reproduced in the Massachusetts Agricultural Repository and Journal under the title "The natural history of the cankerworm," in October, 1796. This first paper was followed by "Natural history of the slugworm" (the common cherry slug), published in 1799; "An important communication relative to the cankerworm," 1816; "On the insects which destroy the young branches of the pear tree and the leading shoot of the Weymouth pine," 1817; "Some notice of the insect which destroys the locust tree," 1818; and "Insects which affect the oaks and cherries," 1819, all of these articles being published in the Massachusetts Agricultural Repository and Journal.

FIRST OFFICIAL ENTOMOLOGIST AND HIS WORK IN MASSACHUSETTS.

Dr. Thaddeus William Harris (1795–1856) was probably the first American entomologist to receive public compensation for his labors, and in this sense he may be called the earliest official entomologist in this country. His first entomological article, entitled "Upon the natural history of the salt-marsh caterpillar," was published in 1823[1] and illustrated by an excellent full-page steel-engraved plate. Although it does not appear from the title, the article was of a distinctly economic character. The introductory paragraph reads as follows: "In the present state of agriculture, hay has become an important product to the farmer in this vicinity. From the high price and the increased demand for the imported and cultivated grasses, the indigenous and natural growth of the soil must rise in value; and of this perhaps none is more valuable on the seaboard than that of the salt meadows."

Dr. Harris shows that the ravages of insects in the salt meadows, particularly of caterpillars and grasshoppers, had become formidable, and states that the object of his paper is an attempt to elucidate the natural history of the caterpillars, "with the hope that it may lead to

[1] Massachusetts Agricultural Repository and Journal for 1823, pp. 322–331.

some sure method of exterminating them, or of limiting their ravages to a shorter period." After a full account of the life history of the species and of the dates of transformation, bringing out the interesting point that the caterpillars are imbued with so great a vitality that long immersion in water does not destroy their life, he concludes by recommending, first, that the grass should be cut early in July, and, second, that the marshes should be burned over in March. It was, in fact, a good, plain, practical paper.

The publication of Dr. Harris's first paper was followed by a constant succession of interesting and valuable articles, published for the most part in the New England Farmer, more than half of them being devoted to the economic bearings of entomology. In 1831 he prepared a catalogue of insects, which was appended to Hitchcock's Massachusetts Geological Report, and at a later period he was appointed by Massachusetts as one of a commission to make a more thorough geological and botanical survey of the State. In this capacity he prepared his noted classic report on insects injurious to vegetation, first published in full in 1841, the portion on beetles having appeared in 1838. He reprinted the work under the name of "treatise" instead of "report" in 1842, and again in revised form in 1852. The whole sum received by him from the State for this labor was $175. After his death the work was reprinted by the State in its present beautiful form, with wood engravings which marked an epoch in that art. The practical value of Dr. Harris's work has been vast. His scientific reputation has steadily grown. His book is to-day as valuable as it was when first written, more than fifty years ago. On entering any entomological workshop in the land the first book that will catch the eye upon the desk is a well-worn copy of the "Treatise upon insects injurious to vegetation." He was fortunate in having a new field; but it is impossible to conceive that this field could at that time have been more intelligently worked, from both the scientific and the practical standpoint. Many new insect pests have been studied since his time, and many new and practical ideas in regard to the warfare against injurious insects have been advanced; but no one has had to do over the work which Harris did so well. He kept constantly in mind the idea that it is necessary to know the life history of the insect before suggesting remedies, and although in his work he had little to say about insecticides or their application, he was successful in many instances, as in the case of the salt-marsh caterpillar, to which reference has been made, in showing that after the life history and periods of transformation of a given insect foe are accurately known, some slight variation in cropping or in agricultural methods will do away with the loss. This important idea was lost sight of until comparatively recent years, and even of late the great developments in the mechanical destruction of insects caused it to become temporarily obscured; but there can be no doubt that as a general upon the Pacific coast and with increasing commercial relations with countries beyond the Pacific, injurious insects have at last begun to reach us from a westward direction. From this it will be seen that as the century has grown older the need of remedies against insects has grown greater. Fortunately in this case, the supply of remedies has commensurately satisfied the demand, and the nation has not failed in this direction to justify its claim to be called "a practical people."

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INVESTIGATIONS BY THE STATE OF NEW YORK.

In his economic line Harris worked practically alone throughout the greater part of his career, until during the latter part of his life, when Dr. Asa Fitch, of New York (1809–1879), began to write for different agricultural journals about injurious insects. Two years before the death of Harris, in 1854, the New York State legislature made an appropriation of $1,000 for an investigation of insects, especially of those injurious to vegetation, and authorized the appointment of a suitable person to perform the work, the matter being placed in the hands of the New York State Agricultural Society. Dr. Fitch received the appointment, and from 1854 to 1870, with the exception of the years 1859, 1865, and 1868, he published an annual report in the "Transactions of the New York State Agricultural Society." The value of his labors was great. In his fourteen reports the great majority of the injurious insects of the State of New York received more or less detailed consideration, and in most cases the life histories of the insects treated were worked out with great care. The remedial measures which he suggested have, however, been largely improved upon, and the practical value of the reports to-day rests almost entirely on the life-history side.

COMMENCEMENT OF INVESTIGATIONS BY THE GENERAL GOVERNMENT.

At about the time when the State of New York began her annual appropriation to support State work in economic entomology, the General Government, in a small way, took up the same line of investigation. Townend Glover was appointed on June 14, 1854, by the Commissioner of Patents to collect statistics and other information on seeds, fruits, and insects in the United States under the Division of Agriculture of the Patent Office. His first report, illustrated by six plates engraved on stone by the author, was published in the Annual Report of the Commissioner of Patents for 1854, and comprised some consideration of the insects injurious to wheat, the cotton plant, and the grapevine; also of the plum curculio, codling moth, and peach borer, closing with an account of the more common species of beneficial insects. His second report, in 1855, continued the consideration of cotton insects and contained some account of insects affecting the orange. He published nothing in 1856 and 1857, but in 1858 he continued his report upon orange insects. He then resigned his position, to be reappointed in 1863, shortly after the establishment of the Department of Agriculture as a separate institution. From that date his reports follow consecutively down to 1877. From 1856 to 1866 Fitch and Glover had the field in economic entomology in the United States practically to themselves.

OCCASIONAL ENTOMOLOGICAL WRITERS.

Occasional entomological articles were published in agricultural and other journals, among the writers of which may be mentioned Miss Margaretta H. Morris, Dr. William Le Baron, James Kirkpatrick, Dr. S. S. Rathvon, Dr. S. S. Haldeman, Cyrus Thomas, Thomas Affleck (in the South), and, beginning in 1864, Dr. Isaac P. Trimble.

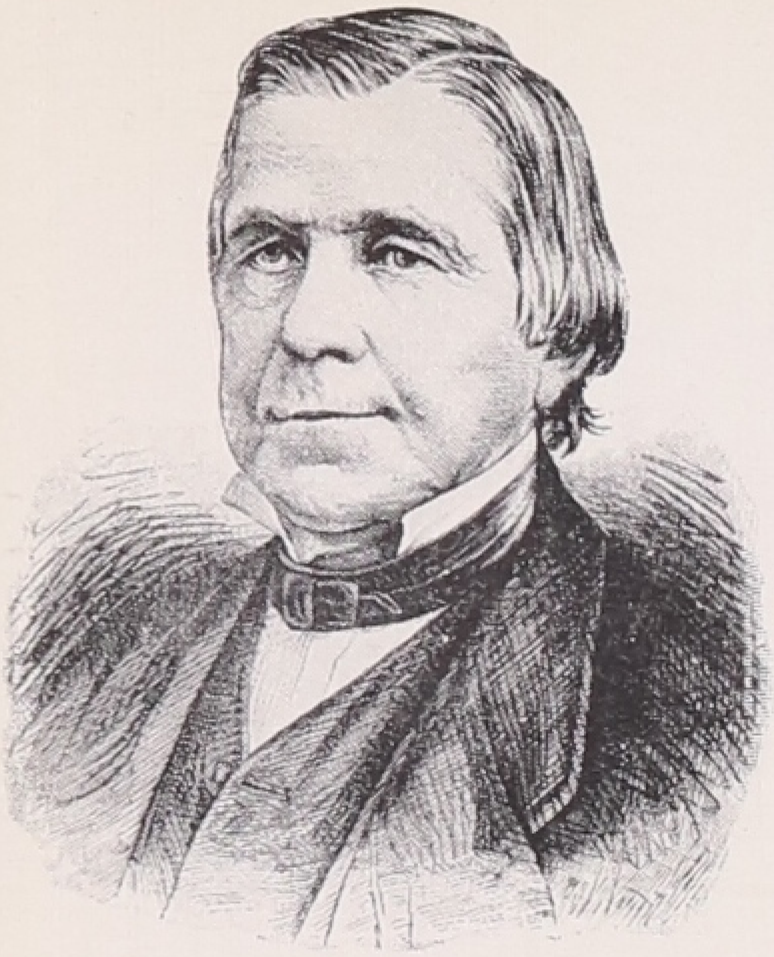
INVESTIGATIONS BY THE STATE OF ILLINOIS.

In the above list we have not mentioned perhaps the most forcible and clearest of all, a man who combined in the highest degree practical ideas with scientific attainments, for the reason that he deserves separate and independent mention. This was Benjamin D. Walsh (1808–1869). He began to write on economic matters in 1860, and continued to do so with great prolificacy until the time of his death, publishing in all three hundred and eighty-five articles upon injurious insects. In 1865 he founded the first journal devoted to economic entomology in this country, and the writer is inclined to believe the first in the world. It was entitled "The Practical Entomologist," and was published by the entomological society of Philadelphia, lasting through two volumes of twelve numbers each, being discontinued in September, 1867, for lack of financial support. In the meantime, however, the Illinois State legislature during the winter of 1866–67 passed a law, as the result of a petition from the State horticultural society, enacting that a State entomologist be appointed by the governor with a salary of $2,000 per annum for a period of two years. At a special session of the legislature held in June, 1867, the governor sent in the name of Mr. Walsh for confirmation, but the senate postponed action upon it until the next regular biennial session in the winter of 1868–69; hence, it follows that Mr. Walsh's first and only official report was published as acting State entomologist, its preparation having been delayed by a long period of ill health which preceded the railway accident that was the immediate cause of his death.

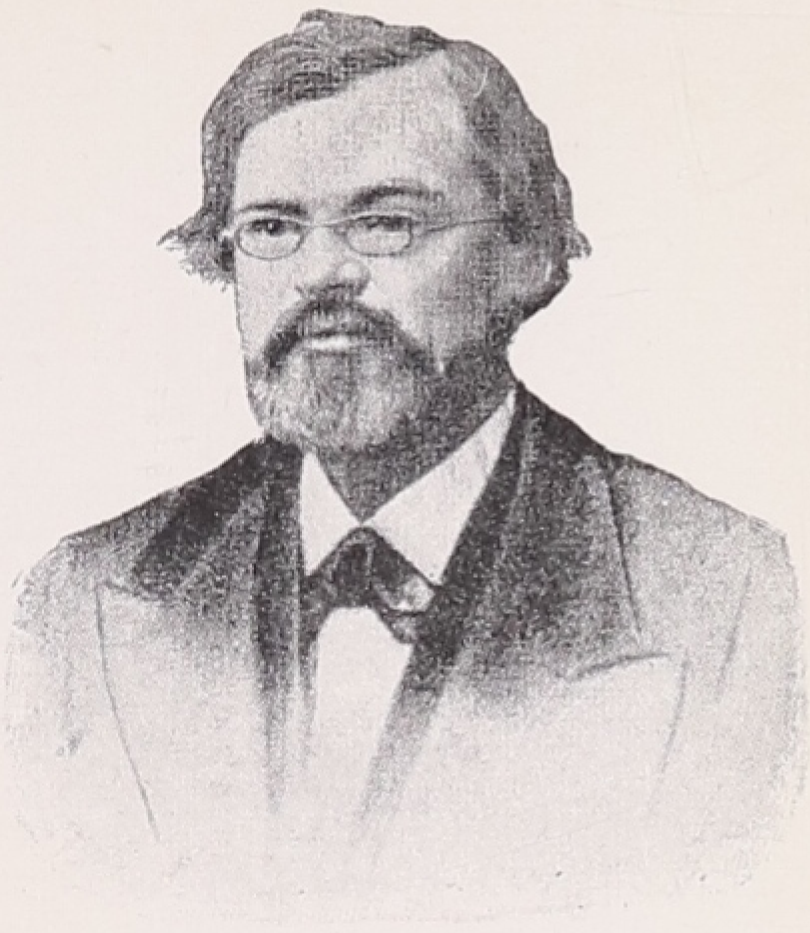
Walsh was a very forcible character, a ready writer, and a ready public speaker, and by virtue of his strong personality, as well as by a marked hatred for fraud and pretense, was the best man who could have been found to place the comparatively new field of investigation upon a firm basis. He showed up prevalent quack remedies in the most scathing and at the same time humorous manner, and attracted new workers to his school. An instance in his career, illustrating his power as a speaker, reminds one of the circumstances surrounding the so-called "lost speech" of Abraham Lincoln. Walsh delivered a lecture before the Illinois State Horticultural Society in January, 1860. He spoke extemporaneously for two hours, communicating his ideas in such a manner as to hold the audience perfectly. The reporter of the lecture stated that he became so intensely interested that his hand refused to move his pencil. In 1868, in joint editorship with Charles V. Riley, Walsh started a second journal devoted largely to economic entomology, which was known as the "American Entomologist," and which also lasted through two volumes before lack of funds caused its publication to cease.

INVESTIGATIONS BY THE STATE OF MISSOURI.

Up to this time we have seen that three States had given official support to scientific work on the subject of injurious insects, namely, Massachusetts, New York, and Illinois, although the Massachusetts support, as already shown, was of a most meager character. In 1868 the State of Missouri joined the list by the appointment as entomologist, of Charles V. Riley, who entered upon his duties on April 1 of that year, and published his first annual report the following December. From that date there followed, annually, eight additional reports, the ninth being submitted March 4, 1877, and covering the year 1876. At the time when Riley began his work, in spite of what had been done by the isolated labors of the men we have mentioned, the study of economic entomology in the United States compared most unfavorably with that in Europe. There elaborate works prepared by well-known naturalists had been published at Government expense, and smaller treatises on the subject of insects injurious to gardens, fields, and forests had frequently appeared, while the subject was taught in the numerous agricultural colleges and schools, especially in Germany. But with the beginning of the publication of the Missouri Reports, and perhaps even a little earlier—with the influence of the practical-minded Walsh, with whom Riley had been intimately associated for several years—the United States was about to begin a rapid progress in this direction, which ultimately placed her at the head of all other countries. Riley's nine reports were monuments to the State of Missouri, and more especially to the man who wrote them. They were original, practical, and scientific. They covered a very great range of injurious insects, and practically all the species which were especially injurious during those nine years received full and careful treatment. These reports may in fact be said to have formed the basis for the new economic entomology of the world, and they included a multitude of observations and intelligent deductions which have influenced scientific thought. Their value to the agriculturist, as well as to scientific readers, was greatly



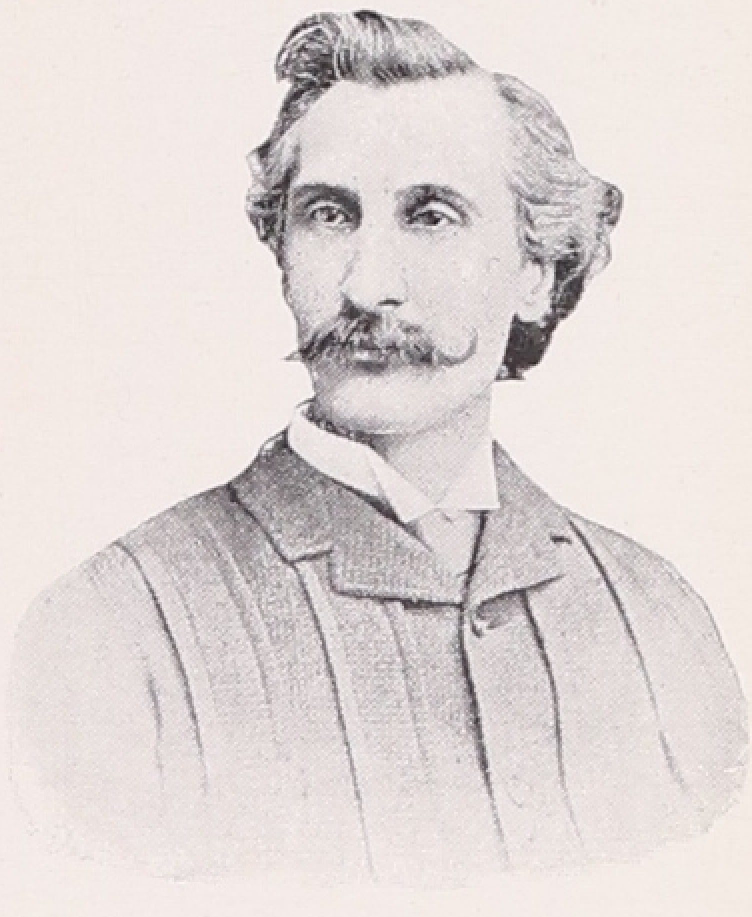
ASA FITCH.



TOWNEND GLOVER.

T. WM HARRIS.

BENJ. D. WALSH.



C. V. RILEY.

SOME WORKERS IN ECONOMIC ENTOMOLOGY.

enhanced by a remarkable series of illustrations, which were drawn by the author and engraved upon wood by the most skillful wood engravers of that time.

BEGINNING OF A PERIOD OF GENERAL INTEREST IN ENTOMOLOGY.

While the Missouri Reports were being published, Dr. William Le Baron was appointed State entomologist of Illinois, an office which has been continued down to the present time, and the work of Le Baron and his successors, Cyrus Thomas and S. A. Forbes, has contributed in a marked degree to the progress of the economic application of entomology. During the Missouri period the well-known zoologist, A. S. Packard, acted as entomologist to the State board of agriculture of Massachusetts, and published three reports, covering the years 1871, 1872, and 1873; a number of young men also began to interest themselves in this line of work, and appreciation and interest on the part of the farming and fruit-growing population steadily grew.

In 1877 the United States Entomological Commission was founded by act of Congress and placed under the charge of the Secretary of the Interior, who appointed as members of the commission Charles V. Riley, A. S. Packard, and Cyrus Thomas. This commission, established for the purpose of investigating the ravages of the Rocky Mountain locust, or Western grasshopper, an insect which had destroyed the crops of certain Western States during the years 1874–1876, existed for several years and published five reports of lasting value, as well as seven bulletins.

In 1878, Townend Glover's health having failed, Riley, fresh from his successful labors in Missouri and from the completion of the first volume issued under the entomological commission, was appointed entomologist of the Department of Agriculture in succession to Glover. He held the office for a year and resigned, owing to a misunderstanding with the authorities. He was succeeded by J. H. Comstock, of Cornell University, who held the office for two years, when Dr. Riley again took charge of the Government entomological work, continuing until June, 1894. During the successive incumbencies of Riley and the intervening term of Comstock the Government work constantly improved, became more and more appreciated, and was an all-important factor in the development of public interest and appreciation. (For portraits of Harris, Fitch, Walsh, Riley, and Glover, see Pl. III.)

INVESTIGATIONS BY THE STATE AGRICULTURAL EXPERIMENT STATIONS.

A most important step was taken when the so-called Hatch Act passed Congress, under which agricultural experiment stations were established in all of the States of the Union. Most of the stations were organized in the spring of 1888. A number of entomologists were soon appointed and active work began practically in the month of February. The first entomological bulletin published by any of the experiment stations was issued in April, 1888, from the Arkansas station, by S. H. Crossman, and was entitled "The peach-tree borer and the codling moth." Bulletins from Hulst in New Jersey, Morse in California, Tracy in Mississippi, Ashmead in Florida, and Weed in Ohio, followed in May. Popenoe in Kansas, and Perkins in Vermont, published one each in June, and Fernald in Massachusetts, and Lugger in Minnesota, published one each in July. This movement, the importance of which to American economic entomology can hardly be overestimated, is too recent to require full historic treatment at this time. Activity in this branch of the work has increased with very great rapidity since 1888, and the character of the work done is on the whole better in almost corresponding ratio. Early publications were, largely as a matter of necessity, compilations. It was desirable to inform State agricultural constituencies of what was already known. With the gradual increase in libraries, laboratory facilities, and financial support, as well as appreciation on the part of farmers, opportunities for original investigation and experimentation have been gradually increasing until the present time. The majority of the entomologists of the State agricultural experiment stations are now in position to add to entomological knowledge and to do practical field work of value, and they are taking advantage of these facilities in a most praiseworthy manner. Of course, a large share of the influence of the work of these offices is gained through their correspondence with agriculturists and through addresses before farmers' institutes and other agricultural gatherings; but judging by the publications alone the gain has been very great. During the calendar year 1898, for example, sixty-one separate publications were issued by the different State experiment stations, either devoted entirely to matter on economic entomology or containing articles upon the subject, the total number of pages on applied entomology reaching nearly 1,400. During the same period nineteen separate publications on economic entomology were issued by the Department of Agriculture, containing a total of about 1,000 printed pages.

FOUNDING OF THE ASSOCIATION OF ECONOMIC ENTOMOLOGISTS.

The founding of the Association of Economic Entomologists in 1890 was an important step in the progress of the application of agricultural science. It has brought together in its annual meetings working economic entomologists of different parts of the country, placed them in personal relationship with one another, enabled them to discuss questions of general remedies, and has helped them to broaden their local entomological horizons. By virtue also of a regulation which admits to corresponding membership persons engaged in economic entomology in other parts of the world and which provides for the constant interchange of publications between all members of the association, the desirable object has been reached of a compact and rather intimately associated union of all the workers in all parts of the world engaged in this particular subject, a condition which it is believed does not exist in any of the other sciences as applied to agriculture. This broad movement, originating in the United States and carried on almost entirely by American workers, deserves special mention in an account of the progress made in this country.

DISCOVERY OF SAN JOSE SCALE IN THE EASTERN UNITED STATES.

An historical account of American progress in economic entomology in the present century would be a poor one indeed if it did not mention the one thing which perhaps more than any other aroused general interest in the subject and brought the economic entomologist most prominently to the front. We refer to the discovery of the existence of the San Jose scale in the Eastern United States in the year 1893. This insect, introduced into the United States from some unknown region, made its appearance in the vicinity of San Jose, Cal., late in the seventies. It spread rapidly over the State of California and was soon known as the most dangerous enemy to deciduous fruit trees on the Pacific coast. In 1887 or 1888 two innocent nurserymen living in New Jersey unwittingly brought it to the East upon nursery stock. Its presence was not discovered until 1893, when it had already been spread far and wide upon shipments of young trees. So great an industry had the sale of nursery stock become and so rapid was the multiplication of the insect that without another introduction of the scale from California the product of these two introductions into the East had in six or seven years been spread through portions of almost every one of the Eastern and Middle States. The scale established itself at almost every point where it was introduced except in certain northern localities, where the climate appears to have been too cold for its development, and it multiplied so excessively as to cause the death of thousands of trees before its presence became known. It was first found at Charlottesville, Va., and other infested localities were discovered in 1894. Warning publications were issued to fruit growers and nurserymen, and year after year discoveries of its occurrence in unsuspected regions multiplied until in 1897 and 1898 it was seen that there was hardly an important fruit-growing region in the United States which was not directly threatened by the pest. In the meantime there was the greatest activity with regard to the insect on the part of economic entomologists, agricultural and horticultural societies, agricultural journals, and State organizations. The literature relating to the insect became very great. Its bibliography by July, 1898, comprised several hundred titles of permanent record and several thousand titles in ephemeral publications. It occupied the attention of nearly every meeting of farmers and fruit growers that was held in the United States from 1894 to 1898, from the village club to the great State agricultural or horticultural society. It was the exciting cause of a national convention of fruit growers, farmers, entomologists, and nurserymen which was held in Washington, D. C., in the spring of 1897. It has been the subject of legislation in eighteen States of the nation and its suppression the principal object of two bills which were laid before Congress.

The general spread of this destructive insect worked great hardship to many fruit growers, and was the cause of the loss of many thousands of dollars; but looking at it in another way, the writer is firmly of the opinion that it has already been productive of great good and that its ultimate effect will be shown to have been most beneficial. Some of the State laws and the regulations which have been adopted to take effect under the provisions of these laws may not be wholly justified or thoroughly wise, but much beneficial legislation has been enacted, and no one cause has begun to operate so strongly as this in indicating the economic value of entomological knowledge and of Government support to entomological investigations, while the actual practical work which has been done against this insect by the small army of workers has greatly increased our knowledge of the action of insecticides, both upon insects and upon plants, and of the best methods of applying them.

PROGRESS IN REMEDIAL DISCOVERIES.

EARLY REMEDIES.

The remedial recommendations of the first sixty years of the century were on the whole not very valuable. A few common-sense suggestions were made, based upon a thorough knowledge of the life histories of certain insect pests, due almost entirely to the work of Harris and Fitch and in a lesser degree to the observations of Peck, although in this connection it should also be stated that excellent work was done on the Angoumois grain moth, or so-called fly weevil, of the South by two Southern planters, namely, Landon Carter and Edmund Ruffin. The majority, however, of the recommendations published in the agricultural journals and reports were theoretical and frequently nonsensical, seldom based on any accurate knowledge of the insect's life history, and sometimes derived from European sources. The following short list has been gathered in a haphazard way from publications of the period, and will serve to illustrate the general character of the recommendations:

To protect cabbages from the depredations of caterpillars.—Sow a belt of hemp seed around the borders of the ground when the cabbages are planted.—*New England Farmer, June 25, 1830.*

Cankerworms.—Use leaden gutters filled with some fluid over which the grub could not pass. Lamp oil is recommended.—*New England Farmer, July 13, 1831.*

Cankerworms.—Make a band of chestnut burrs by stringing them together with strong twine and tie around the trunk.—*New England Farmer, April 9, 1834.*

Bot-fly of the horse.—Scrape off the eggs every ten days with a sharp knife. Phlebotomize over the jugular vein and use mild oils freely.—*New England Farmer, May 5, 1826.*

Cankerworms.—Strew slacked lime an inch thick around the trees to the extent of 3 or 4 feet from the roots.—*New England Farmer, July 7, 1826.*

Cankerworms.—Tarring the trees.—*New England Farmer, July 25, 1828.*

Slugworms.—Dusting lime on the leaves by suspending an old seive on a long pole.—*New England Farmer, July 25, 1828.*

Rose-chafer.—Slacked lime applied from a dredging box while the fruits or plants are wet with dew, wetting the plants first with a weak solution of gum arabic.—*New England Farmer, May 8, 1829.*

Cankerworms.—Scrape the trees and tie on bands of hair rope.—*The Cultivator, April, 1838.*

Tent caterpillars.—Fasten a bottle brush (made to clean the insides of bottles and composed of hogs' bristles introduced between two stiff wires closely twisted) to a long pole, press it on the small nest, turning the pole in hand and tangling and removing the web.—*Timothy Pickering, in Massachusetts Agricultural Journal, Vol. IV, July, 1817.*

Pea weevil.—Let everybody feed all of their peas to their cattle and import a new stock of seed from Europe.—*William Bartram, in Memoirs Philadelphia Society for Promoting Agriculture, Vol. I, 1815 (read July 4, 1789).*

Plum curculio.—Suspend bits of board about the size of a case knife, dipped in tar, on the tree as a deterrent. Make a pavement about the tree by placing flat stones cemented with lime cement. Give hogs the run among the trees to destroy the fallen fruit.—*William Bartram, in Memoirs Philadelphia Society for Promoting Agriculture, Vol. I, 1815, Appendix, pp. 34–38.*

Hessian fly.—Destroy the stubble of grain soon after harvest by burning or otherwise.—*Jonathan N. Haydens, in Transactions Society for Promotion of Agriculture for New York, Vol. I, 1792, pp. 89–107.*

Caterpillars on trees (presumably tent caterpillars).—Bore a hole into the tree about 6 inches deep and fill it with sulphur, a remedy which is said to have never failed. Several cases instanced.—*George Webster, Albany, in Memoirs Board of Agriculture State of New York, Vol. II, 1823, p. 251.*

All insects on trees.—Sulphur plug.—*Farmers' Register, Vol. I, 1834, p. 149.*

Moths in wheat.—Mix large parcels of the twigs of the China tree with the wheat. In one fortnight, on experiment, not a weevil was to be found.—*Farmers' Register, Vol. I, 1834, p. 227.*

Hessian fly.—Late sowing.—*Farmers' Register, Vol. I, 1834, p. 310.*

Peach-tree borer.—Remove the soil around the base of the trunk, put in a composition of clay and ashes, and wrap stiff brown paper around the tree to the height of a foot.—*Farmers' Register, Vol. I, 1834, p. 417.*

A rather elaborate article was published as a prize essay of the New York State Agricultural Society in 1843[1] under the title "A treatise on insects injurious to field crops, fruit orchards, vegetable gardens, and domestic animals, with a description of each and the best methods of destroying them or preventing their ravages." This essay, which covers about fifty pages, contains practically nothing original, and some of the remedial recommendations are rather amusing. For example, in writing of the wheat midge, the author says: "Fumigating the fields with sulphur or smoke from any materials will retard their action for a time, and, could it be continued, might destroy them.

[1] Transactions New York State Agricultural Society, Vol. III, 1843.

All pungent odors are offensive to the grain fly, as they are to the mosquito, and that most offensive of all odors, the one proceeding from the skunk, has been tested and highly recommended as a preventive."

It was this sort of work that especially aroused the indignation of Walsh. The caustic manner with which he showed up the unfounded utterances of impractical and ignorant persons may be illustrated by his comment upon a newspaper article which recommended banding trunks of trees as a remedy for all the insects which injure trees:

The worm in fruit trees! As if fruit trees were not afflicted by hundreds of different worms, differing from each other in size, shape, color, and habits of life, time of coming to maturity, etc., as much as a horse differs from a hog. Yet the universal bandage system is warranted to kill them all. Does the apple worm bore your apples? Bandage the butt of the tree, and he perisheth forthwith. * * * Does the web worm spin his web in the branches? Bandage the butt, and he dieth immediately. Does the caterpillar known as the red-humped prominent or the yellow-necked worm strip the leaves off? Bandage the butt of the tree, and hey! presto! he quitteth his evil ways. Does the Buprestis borer bore into the upper part of the trunk? * * * Still you must bandage the butt with the same universal calico, and in a twinkling he vamoseth the ranch. Be the disease what it will, the universal, patent, never-failing pill is certain sure to extirpate it. * * * In obstinate cases it may perhaps be necessary to bandage the whole tree, trunk, branches, twigs, and all; but if you only apply bandages enough, the great bandage anthelmintic vermifuge is sure to be a specific against the genus worm. The genus bug may perhaps require a distinct prescription; something in the nature of a cataplasm or an emollient lotion. * * * Long live King Humbug! He still feeds fools on flapdoodle, and many of them have large and flourishing families, who will perpetuate the breed to the remotest generation.

A NEW ERA IN REMEDIES.

With the writings of Walsh, immediately followed by those of Riley, a new era of excellent remedies founded upon accurate knowledge of the economy of the insects in question began. Aside from the excellent recommendations which had been made with regard to agricultural practice, as it has been termed, and which refers to such matters as rotation of crops, different times of planting and harvesting, and different methods of cropping, etc., the first great start which the new economic entomologist received from the remedial standpoint was probably the introduction of Paris green as an insecticide.

Paris green.

At the time this substance was introduced, the best insecticides in use were the various forms of soap, tobacco, quassia chips, carbolic acid, and hellebore, although the last was a comparatively new remedy and came into general use at about the time of the spread of the imported currant worm in the late fifties. The spread of the Colorado potato beetle into the Eastern States between the years 1859 and 1872 started a great deal of experimental work in regard to remedies, and Paris green was first used at some time early in the sixties. The name of the first man to use it is not known, but by 1868 it was being used by several persons. The editors of the American Entomologist

(Vol. I, p. 219, July, 1869) recommended it confidently as a result of experiments tried both in 1868 and 1869, and in the former year Mr. J. P. Wilson, of Illinois, took out a patent for one part Paris green and two parts mineral paint, to be used to kill potato bugs. The use of Paris green against the cotton caterpillar seems to have been first suggested by Riley at the St. Louis meeting of the National Agricultural Congress in 1872, although in January, 1871, T. W. Mitchell, of Texas, secured a patent for the use of a solution of arsenic against this insect. Its extensive use against the cotton caterpillar has been a great boon to the cotton planters of the South.

In 1872 Dr. Le Baron recommended the use of Paris green against the spring cankerworm, which was abundant that year. This was the first recommendation for its application to fruit trees. Four years later Prof. A. J. Cook repeated the recommendation, and in 1878 the advice was followed by many apple growers in Michigan. In 1878 Mr. J. S. Woodward, of Lockport, N. Y., advised Mr. Edward P. Haynes, of Niagara County, N. Y., to spray his apple trees with Paris green against cankerworms. The following autumn Mr. Haynes noticed that the apples in the sprayed part of the orchard were much less infested by the codling moth than in other parts of the orchard. Mr. Woodward visited the orchard, verified this fact, and reported it at the January meeting of the Western New York Horticultural Society. Mr. Woodward, writing to the late E. G. Lodeman, when the latter was engaged in preparing his work entitled "The spraying of plants," said: "I shall never forget this, because of the way in which I was jumped upon as a crank." Almost at the same time the same discovery was made by Professor Cook, in Michigan, and by Hon. John M. Dixon, of Oskaloosa, Iowa, the latter, however, using London purple instead of Paris green.[1] This discovery has resulted in the use of arsenical poisons in enormous quantities in regular orchard work. It was adopted slowly, on account of the supposed danger from its use. Even Riley, who had been so prominent in urging the use of arsenical poisons against the Colorado potato beetle and the cotton caterpillar, writing in the Farmers' Review, in the autumn of 1880, says:[2]

Professor Cook, of the Michigan Agricultural College, has lately recommended them [Paris green and London purple] for the killing of a strawberry leaf-beetle (*Paria aterrima* Oliv.), which, as he shows, lives in its larva state beneath the ground; also for the destruction of the apple worm. In the first instance it were eminently dangerous to use such a poisonous remedy while the plants are fruiting, and I would not recommend it even later in the season until every other available remedy had been tried. In the second case it is even less to be recommended. It will undoubtedly serve to kill many of the first brood of worms, and this is desirable; but there is as good evidence that lime or plaster dusted onto the young

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[1] See the writer's article on the codling moth, in the Annual Report of the Department of Agriculture, 1887, pp. 88–115, for a discussion of this question.

[2] See American Entomologist, Vol. III, p. 244.

fruit has much the same effect, while experience has shown that the bandage system and other methods of fighting this insect, when judiciously and persistently adopted from year to year, are sufficient to insure a crop at trifling cost. Finally, if the poison is so persistent in the calyx as to have any effect in destroying the second brood of worms, that will only heighten the danger to those persons who subsequently eat the fruit.

Professor Cook, in a paper read before the American Association for the Advancement of Science at its Boston meeting, in 1880, as well as in subsequent papers read before the Michigan Horticultural Society and the Society for the Promotion of Agricultural Science, gave his annual experience, and was the most ardent advocate of this treatment for codling moth. The careful experiments made by Forbes in 1885 added great weight to the remedy, on account of his wide reputation for care and conservatism. E. S. Goff, then at Geneva, N. Y., also published results of some careful experiments made in 1885. In 1887 experiments made by W. B. Alwood and E. H. Cushman for the Division of Entomology emphasized the value of the treatment, which the writer did not hesitate to strongly recommend in his article on the codling moth, published that year. As Lodeman has shown, however, very few of the most progressive orchardists adopted the remedy until after the establishment of the State agricultural experiment stations in the spring of 1888, when added emphasis was given by the experiments and recommendations of the newly appointed entomologists and horticulturists.

The same substance, Paris green, was first recommended against the plum curculio by Mr. G. M. Smith, of Berlin, Wis., in 1871, but the idea that it would be efficacious was generally discredited. Mr. J. Luther Bowers, of Herndon, Va., used it in 1880 with good results. Mr. William Creed, of Rochester, N. Y., recorded the complete success of two years' work against the insect in Purdy's Fruit Recorder, in November, 1885, and during the same year Forbes experimented most carefully in Illinois. In 1887 W. B. Alwood and Herbert Osborn, working for the Division of Entomology; A. J. Cook, in Michigan, and C. M. Weed, in Ohio, also carried out successful experiments, and the remedy has since come into general use. By 1887, in fact, arsenical poisons had become the standard remedy against nearly all mandibulate or gnawing insects. Their use in other countries has been brought about very slowly, and they have but slight vogue in Europe to-day. Miss Ormerod, in her numerous reports, has recorded the difficulty which she has experienced in securing their adoption by English orchardists. The English colonists, however, more enterprising and less conservative than the home people, have taken them up, and they are used to-day in New Zealand, Australia, and South Africa.

Arsenical compounds.

Much experimental work with different arsenical compounds has been carried on in the United States since Paris green made its appearance. London purple, a by-product in the manufacture of aniline dyes, was introduced through the efforts of a London house in the early eighties, and it has been used to a very considerable degree. Its peculiar color was considered a strong argument in favor of its use on account of the ease in distinguishing sprayed plants and on account of its ready recognition as a poison. This latter argument failed in one instance, at least, as was pointed out by the late Dr. W. S. Barnard, who, on one occasion, while traveling on a Mississippi River steamboat, discovered that the London purple sifting through sacks in the cargo had been used by the enterprising steward to color the ice cream which was served to the passengers. The variable amount of arsenic contained in this compound, however, renders it a less satisfactory substance to use than some of the other arsenical combinations. The use of common white arsenic, especially when mixed with lime, has been recommended, and its experimental use in this combination was first tried and advocated by Gillette when connected with the Iowa experiment station. A compound known as arsenate of lead has come into somewhat general use in the last few years. This substance was first used by the gipsy-moth committee of the Massachusetts State Board of Agriculture in its work against the gipsy moth, an insect which is able to consume a considerable quantity of arsenic without harm, from which fact a poison was needed which could be sprayed upon the trees in very strong solution. The lead compound enabled its use in great strength without the ordinarily resulting damage to the foliage. Later compounds are the simple arsenite of copper, first recommended by Mr. C. L. Marlatt, of this office, and a mixture recommended by Professor Kedzie, of the Michigan Agricultural College, in the following proportions:

White arsenic	pounds	2
Sal soda	do.	4
Water	gallons	2

Boil together for fifteen minutes; then slake 2 pounds of lime and stir it in 40 gallons of water, adding a pint of the above mixture.

The simple arsenite of copper is preferable to Paris green on account of its smaller cost and in being a very fine powder, which remains easily in suspension. It contains about 50 per cent of arsenic, and is marketed under the name of green copper arsenite.

Kerosene emulsions.

Another distinct and very important advance in the line of remedial application was the general adoption of kerosene, emulsified so as to stand dilution with water, against sucking insects. The insecticide properties of pure kerosene have long been known. Lodeman has shown that kerosene was recommended for the destruction of scales on orange trees in 1865,[1] and was also successfully applied to

[1] Gardeners' Monthly, December, 1865, p. 364.

oleander, sago palm, acacia, and lemon trees. This, however, was only greenhouse work, as the oil was poured into a saucer and applied by means of a feather. The Gardeners' Monthly the following year recommended it for destroying all insect life, but modified this recommendation later by the statement that the vegetable oils were safer. Mr. William Saunders, of the Department of Agriculture, told the writer, in 1878, that he had been using a mechanical mixture of kerosene and water in greenhouse work for many years. Mr. George Cruikshank, of Whitingsville, Mass., used a mixture of kerosene and whale-oil soap as early as May, 1870, practically producing an emulsion.[1] Henry Bird, of Newark, N. J., in 1875, made a mixture in which he used a little kerosene oil with strong soapsuds, finding that it combined readily, and could be applied uniformly with a syringe.

In 1878 A. J. Cook[2] recommended a mixture of kerosene oil and soapsuds. In 1880 W. S. Barnard, working for the United States Entomological Commission, suggested and produced an emulsion of kerosene with milk, which was used with some success. In the winter of 1881–82 H. G. Hubbard, working for the Division of Entomology, made a stable milk emulsion with condensed milk, which he used successfully against scale insects on orange trees, and in 1884 the same investigator originated by experiment the standard kerosene-soap emulsion now commonly known as the "Riley-Hubbard formula." Cook, working in Michigan, had arrived at a different formula, and his failure to make a good emulsion by the "Riley-Hubbard" formula was shown by Marlatt to be due to the exclusive use of very hard water at the Michigan Agricultural College. This kerosene-soap emulsion, generally made according to the so-called "Riley-Hubbard formula," was speedily adopted, and has become one of the most used and most reliable insecticides against all sucking insects. (See Yearbook for 1896, footnote to page 232, for mention of a possible earlier use of kerosene emulsion.)

Hydrocyanic-acid gas.

Another very important insecticidal process which has come into use during the last fifteen years is that of fumigation with hydrocyanic-acid gas, although the introduction of this process has had by no means the same far-reaching effects as the discovery and general use of arsenical poisons and kerosene emulsion. The process originated in California as the direct outcome of the efforts of this office against scale insects, the original work being carried on by D. W. Coquillett, a field agent of the Division of Entomology, and F. Morse, of the University of California, and subsequently largely by private enterprise, although experimental work in different modifications of the process was done by Mr. Coquillett, or under his supervision. The plan of covering trees with oiled tents and liberating beneath the

[1] Gardeners' Monthly, February, 1875, p. 45.
[2] Report of the Michigan State Board of Agriculture for 1878, p. 434.

tents a supply of this deadly gas, produced by treating cyanide of potassium with sulphuric acid, was adopted by citrus growers and by county horticultural commissioners to a very considerable extent in California. Its use was practically restricted to this State down to 1895, although some experiments had been made with its use on the island of Montserrat, British West Indies, against scale insects on orange and lemon trees in 1894–95, upon the recommendation of Professor Riley, who visited this island in company with Mr. Hubbard in the spring of 1894. With the development of the San Jose scale work in the East, however, this process was soon introduced in this part of the country. The first experiment made with it was undertaken by Mr. Coquillett on the grounds of Dr. C. H. Hedges, of Charlottesville, Va. (the first point where the San Jose scale was discovered east of the Rocky Mountains), in the month of March, 1894, and the writer of this paper in April, 1894, described the process without especially recommending its use, as at that time the results of the Charlottesville experiment had not become apparent.[1] More recently the process has been carried on, apparently with great success, in Maryland orchards by Prof. W. G. Johnson.

A great and important development of the use of this fumigating process, however, soon took place in its application by nurserymen to their stock before delivery to purchasers. This process, adopted by many nurserymen for self-protection and required by the laws of certain States, was, the writer believes, first recommended by him in conversation with Dr. J. B. Smith, entomologist of the New Jersey Agricultural Experiment Station, in September, 1894, while visiting the nurseries of the Parry Brothers, in New Jersey. Its use in this way was recommended in Bulletin No. 3, new series, of the Division of Entomology, but in the meantime it had been recommended by Dr. Smith in Bulletin No. 106 of the New Jersey station, published November 22, 1894. To Dr. Smith, therefore, belongs the credit of the first published recommendation. Since that time the process has come into very general use. Experiments by Alwood in Virginia and by Johnson in Maryland have resulted in the fixing of methods and in the establishment at many points of buildings erected for the sole purpose of fumigating nursery stock.

Another form of the use of hydrocyanic-acid gas against insects has received consideration during the past five years and has now reached practical results; this is its application against insects affecting greenhouse plants. The greenhouse itself, being a closed building or a building which may be closed, renders the use of the gas at night a comparatively simple matter, but the great variety of plants of varying resistant qualities which are found in greenhouses has rendered necessary extended experimentation in order to insure safety to the plants themselves. The extended work of Messrs. Woods and

[1] Circular No. 3, second series, Division of Entomology, published April 4, 1894.

Dorsett, of the Department of Agriculture, and Mr. Hemenway, of the Massachusetts Agricultural College, as published by the Division of Entomology, has established the usefulness of this application within certain limitations. It seems, however, that specific experiments under all possible varying conditions and upon all possible varieties of plants must be made before the remedy can come into general use.

The three main insecticide discoveries.

The use of arsenicals, of kerosene emulsions, and of hydrocyanic-acid gas are the main insecticide discoveries of the closing portion of the century, and their use as practiced to-day has been dependent upon a great amount of experimental work, carried on, perhaps, mainly by economic entomologists. This experimental work included not only a consideration of the proper proportions of the insecticides when used against different insects, but also a determination of their effect upon the foliage of different plants in different climates, under different local climatic conditions, in different seasons, and even at different times of the day, as well as different methods of preparation involving the points of ease and economy.

Experimental work with other insecticide substances.

A great deal of valuable experimental work has been done also with other substances and mixtures. This work has been of value, even where the results have been negative, as forestalling future labor and especially as putting a quietus upon unfounded recommendations and upon valueless proprietary claims. The extensive experiments with pyrethrum mixtures, for example, which resulted in the establishment of an extensive industry in home-grown pyrethrum powder and in a large series of tests in growing *Pyrethrum roseum* and *P. cinerariæfolium;* the extensive experiments with different whale-oil and fish-oil soaps, begun originally in the work of the Division of Entomology against the hop plant-louse in 1886 and carried on much further in 1895–96 in the work against the San Jose scale; the experimental work with the old quassia chips solutions and decoctions; the series of experiments with supposed insecticidal native plants, and a host of other experiments of similar nature may be cited as evidence of the extent of this work. Probably the most important of the remedies of what may be termed secondary value, and which have been brought forward by this work of recent years, is the use of bisulphide of carbon against insects affecting stored grain.

Machinery for distributing insecticides.

The development of machinery for the application of insecticide mixtures is another great advance in applied entomology made during the past twenty years; and this is a line of work in which especially the horticulturist and also the vegetable pathologist have had a hand. This work first became prominent in the investigations undertaken by the Government both under the Division of Entomology, Department of Agriculture, and under the United States Entomological Commission in the work against the cotton caterpillar in the South.

It is true that in the early days of the march of the Colorado potato beetle toward the East a number of sprinklers and dusters were invented for the purpose of applying Paris green to potato plants; and two or three of these, like "Gray's improved sprinkler," invented by Frank M. Gray, of Illinois, in 1874, and "Peck's spray machine," invented by W. P. Peck, of Pennsylvania, about the same time, were prophetic of the improved knapsack sprinklers which have come into such great use, especially for diseases of the grape in France, and also to a lesser degree in this country. But it was not until the late W. S. Barnard, working under the direction of Riley, invented the admirable eddy chamber, or "cyclone system" of nozzles, following it with the construction of a number of ingenious, but since superseded, machines for the field distribution of the poison that what may be termed the "insecticide-machinery epoch" began. This work was soon after taken up in France, where it has been carried to a high degree of excellence by such firms as V. Vermorel and others, Vermorel inventing a modification of the cyclone nozzle, known there as the Vermorel modification of the Riley nozzle and in this country as the Vermorel nozzle. It was not, however, until the use of arsenical sprays in orchards, against the codling moth in particular, and also against the plum curculio and the cankerworm, became general that the full tide of perfection of insecticide machinery began. As was quite to be expected, so soon as there was a strong demand for such improved machinery intelligent manufacturers took hold of the problem and began to place machines of great excellence on the market. The demand increasing, improvement became more and more abundant, and there are at the present day many firms in the United States putting out distributing machines of a high degree of merit and of almost unending variety, from the hand bucket pump for garden use to the motor engine pumps and machinery for orchard use on a large scale. Many nozzles have been invented since Barnard produced his first rough tin model of the eddy chamber, or "cyclone," as he termed it, but the modifications of his system remain to-day the most generally used and the most efficient and economical of any that have been produced.

WORK OF AN INTERNATIONAL CHARACTER.

In 1889 was brought about by American entomologists the first example of what may be termed beneficial international work in economic entomology. The introduction of *Novius* (*Vedalia*) *cardinalis* from Australia into California, where it utterly destroyed the white or fluted scale, an insect which had damaged the citrus crops of California to the extent of hundreds of thousands of dollars, and which threatened the extinction of the citrus industry of the Pacific slope, is an event which is too well known to need description here. It was also an event which has been termed "epoch-making," and which would deserve the title could it only be often repeated. It opened up, however, in a practical way a line of work which had often been suggested by American writers on entomology (the first of them, by the way, it must be stated, being a Canadian, Rev. C. J. S. Bethune).

The first and successful importations of this beneficial ladybird were made by Albert Koebele, a salaried agent of the Division of Entomology, working under the direction of the late Dr. Riley, but whose traveling expenses were defrayed from the fund appropriated by Congress for the representation of the United States at the Melbourne Exposition. A later trip to Australian regions was undertaken by Mr. Koebele while still on the pay rolls of the Division of Entomology, but his expenses were paid from the appropriation granted by California to its State board of horticulture. The results of this second trip, although not as conclusive as those of his first trip, still demonstrated in marked degree the advantage of this class of international work, namely, the introduction of beneficial insects from one country to another. After Koebele's second trip he resigned his position, and was soon after employed by the newly established Hawaiian Republic for the purpose of continuing the same class of work for that country. From reliable accounts it seems certain that his work along the same line has resulted in great benefit to the agricultural interests of Hawaii, which, since its annexation to this country, has once more made Koebele's work a feature of the economic entomology of the United States.

The United States has been able to assist other Governments in their work against injurious insects. Sendings of the same ladybird (*Novius cardinalis*) to South Africa, to Egypt, and later to Portugal, have brought about results similar to those which proved the salvation of the citrus industry of California, while other less important exportations of beneficial insects promise good results. Through the office which the writer represents there have been several introductions of beneficial insects from foreign countries. Collections of museum specimens of injurious insects of foreign countries have also been made and brought to this country in the course of a study of the greatly increasing danger which enlarging commercial relations and rapidity of ocean traffic are constantly bringing about by the introduction of new insect pests.

A striking exemplification of the benefits to be derived from the prosecution of this international work is actually developing in California in the probable establishment in that State, through the efforts of this Department, of *Blastophaga grossorum*, an insect which in Mediterranean countries fertilizes the Smyrna fig, and which it is confidently expected will result in the building up of a fig industry in California, the output of which will rank favorably with, if it does not exceed, that of the countries which have made the Smyrna fig the standard fig of commerce. At the time of the present writing (December, 1899) four generations of the fertilizing insect have been reared under natural conditions at Fresno, Cal., and there is every probability that it will be carried through the winter successfully. The insect hibernates in so-called gall-figs upon the wild fig tree. Such figs heretofore at Fresno have fallen with the first heavy frost. The present winter, however, a certain number of trees have been protected from the action of the frost by a canvas covering, and a commercial product of American-grown Smyrna figs during the summer of 1900 is confidently expected.

PRESENT STANDING OF THE UNITED STATES IN ECONOMIC ENTOMOLOGY.

The writer has referred in an earlier portion of this paper to the fact that as late probably as 1878 this country was behind certain European countries in its accomplishments in the field of economic entomology, but owing to the crying needs of a rapidly growing population of practical people and to the consequent encouragement given by legislatures in making appropriations, as well as by the energy, ability, and adaptability of the individual workers, many of them men of high standing in the field of pure science, the United States has jumped to the front. English colonists, themselves confronting many of the same problems which we have had to meet, were among the earliest to recognize this fact, and agricultural papers of the Australian colonies, of New Zealand, of Cape Colony, and of British India have for years been extensively quoting from American writings. Other countries have followed their lead. Cape Colony has employed an American economic entomologist. Argentina sent for an American entomologist to advise that Government in its work against migratory locusts. The British West Indies are at the present time in search of the proper man to go from the States to help them in their work along these lines. In 1896 the French authority, Dr. Paul Marchal, writing on the subject of applied entomology in Europe, began his paper with the words (freely translated):

> There exists nowhere an organization dealing with applied entomology capable of rivaling that of the United States. The extraordinary development which this service has taken in America is well known. * * * The progress realized in these later years under the influence of this organization has been of the highest kind. In particular that which concerns the application of insecticides on a large scale and biological observations of a high interest from the point of view of pure science have been accumulated in their publications. * * * European nations have commenced to follow the example which has been given to them on the other side of the Atlantic. * * *

Recently, Miss Eleanor A. Ormerod, the well-known English writer and investigator, referring to the work of American economic entomologists, wrote: "It really is impossible for me to say how highly I fully believe that their serviceable scientific and applied information is benefiting the world as well as their own country."

All this is encouraging, and it appears to the writer, who, however, is perfectly willing to confess that he may be prejudiced, well deserved; yet the rapid strides which other countries are taking will necessitate the most strenuous endeavors on the part of American workers if this temporary supremacy is to be maintained. This, of course, should not be an especial aim of economic investigators in this country, but is perhaps worth the mention. We shall aim to secure the best results possible, and it should be our hope that others in other countries may do as well. The extremely rapidly growing public interest in investigations in this line during the past few years, as well as the excellent results obtained by the workers, are fast placing this country in a position where agriculturists may work to the best advantage in their warfare against injurious insects.

AGRICULTURAL EDUCATION IN THE UNITED STATES.

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INTRODUCTION.

In previous articles in the Yearbooks for 1894, 1897, and 1898 the origin and development of the system of agricultural education in the United States have been discussed, and special features of that system have been described in more or less detail. The main purpose of the present article is to present a general view of the different agencies for education in agriculture in this country as they exist at the close of the nineteenth century, and to indicate the directions in which the movement for the diffusion of knowledge on agricultural subjects among our people is tending. In order that the reader may have a proper understanding of the real significance of the present remarkable activity in the sphere of agricultural education, it is necessary that he should have in mind at least an outline of the history of this movement, and be able to form some estimate of the progress which has been made in defining and organizing the various branches of agricultural education. In presenting such an outline as an introduction to the main theme of this article, advantage will be taken of a recent review of the available literature relating to the history of agricultural education in this country made under the direction of the writer by Prof. Herman Babson, of the Massachusetts Agricultural College, through which additional light has been thrown on the beginnings of various important movements for the promotion of such education.

The activity in agricultural education during the present century will seem all the more impressive if it is remembered that, after the cessation of the efforts of Greek and Roman writers to encourage agriculture by describing the processes of the art, centuries elapsed before the educated men in Europe took interest enough in agriculture to write books about it. War was the chief occupation of gentlemen, and the arts of peace were left to the ignorant and the lowly. But these centuries nevertheless marked the steady progress of civilization, and "soon after the beginning of the sixteenth century agriculture partook of the general improvement which followed the invention of the art of printing, the revival of literature, and the more settled authority of government, and, instead of the occasional notices of historians, we can now refer to regular treatises, written by men who engaged eagerly in this * * * occupation." The first English treatise on husbandry appeared in 1534, entitled "The book of husbandry," and was written by Sir A. Fitzherbert, a judge of common pleas. The voyages of exploration in various hitherto unknown quarters of the globe and the colonization of America brought new agricultural plants and breeds of animals to Europe and caused the spread of the old ones in the new countries. The natural sciences were rapidly developed and investigations relating to agriculture began. Something of the progressive spirit of the age begun to stir in even the dull frame of this oldest of industries, and by the close of the eighteenth century the advance movement in agriculture had taken the form of organized effort. Societies, like the Bath and West of England Society and the Highland Society, were formed in Europe, and a Government board of agriculture was organized by Great Britain.

EARLY EFFORTS FOR THE IMPROVEMENT OF AGRICULTURE.

In this country the first agricultural efforts necessarily were directed toward clearing the land and growing the crops immediately needed for the sustenance of the settlers and for export to the mother country, whence alone manufactured articles could be obtained. As is common in new countries where vast tracts of land are open to free occupation, many speculative attempts were made to grow crops bringing high prices with a minimum of labor. Some of these attempts, like that relating to the production of silk, proved utter failures, while other crops, such as tobacco, were very profitable. Land was so plentiful that in many regions the easiest and most profitable thing to do when yields declined was to change to new fields and abandon the old to weeds. There was little incentive to careful cultivation and scarcely any motive for seeking new knowledge for the improvement of agricultural practice; and to this can be added the general absence of any educational system for the masses, together with the deep-rooted prejudices against "book learning" as applied to any industrial pursuit, especially agriculture. Wars, at first with the Indians and then between the various European nationalities occupying the American continent, engaged much of the attention of the most vigorous portion of the farming community, and these struggles culminated in the united efforts of the colonies to free themselves from Great Britain, which led to the protracted contest known as the American Revolution.

Occasionally some pioneer of agricultural education arose, like Jared Eliot, of Connecticut, who published in 1747 a series of essays on farming "full of valuable suggestions," but little heed was paid to the advice of such men. The Revolution naturally left agriculture in a most deplorable condition, so that the attention of statesmen was almost necessarily drawn to measures for its resuscitation. But far more important for the begetting of a progressive movement in agriculture was the new feeling among the people that this country was to be forever the home of themselves and their descendants. They were no longer adventurous colonists seeking wealth to be taken back to the mother country, but citizens of a young nation with vast possibilities of material development. It was also evident that for a long period agriculture would be the chief industry of the new Republic, and that the development of other industries, as well as success in commerce, depended largely on wise utilization of the agricultural resources of the country. The wisest heads took in the real situation most quickly, and, following the fashion set across the sea, begun a propaganda for agricultural improvement. This was not due to any demand of the people for information, but to a desire on the part of the leaders of thought and action to awaken interest in what they deemed a matter of vital importance to the welfare of the nation. Hence, most of the early agricultural societies were begun in cities, and their membership was largely composed of men who had only a secondary interest in agriculture, though it must be remembered that in those days there were comparatively few Americans in active business, professional, or political life who did not have some direct dealings with farm property.

ORGANIZATION OF AGRICULTURAL SOCIETIES.

The organization of agricultural societies, beginning early in 1785 at Philadelphia, then the national capital, and taking in such men as George Washington, Benjamin Franklin, and Timothy Pickering, spread rapidly south and north along the fringe of Atlantic coast communities, then constituting the United States. At Charleston, S. C., in 1785; Hallowell, Mass. (now Maine), in 1787; New York City, in 1791; Boston, Mass., in 1792; Wallingford, Conn., in 1794; Middlesex County, Mass., in 1794; Sturbridge, Mass., in 1799, and perhaps in a few other places, similar societies were formed prior to the close of the eighteenth century. This movement continued, until in 1809 we have the germ of a national organization in the society formed in the District of Columbia, to which the seat of the National Government had a few years before been permanently transferred.

BEGINNING OF PUBLICATIONS ON AGRICULTURE.

During this period various methods for diffusing agricultural information were proposed or put in operation, very largely through the efforts of these agricultural societies. Books on agricultural subjects began to appear. Among these, mention may be made of a volume of over 300 pages, published at Worcester, Mass., in 1790, entitled "The New England Farmer, or Georgical dictionary: Containing a compendius account of the ways and methods in which the most important art of husbandry, in all its various branches, is or may be practiced to the greatest advantage in this country, by Samuel Deane, A. M., Fellow of the American Academy of Arts and Sciences;" and the "Rural Socrates, or an account of a celebrated philosophical farmer, lately living in Switzerland and known by the name of Kliyogg.—Hallowell (District of Maine). Printed by Peter Edes, and sold by the booksellers in the principal towns of the United States. A. D. 1800." The author of this book was Dr. Vaughan, a prominent member of the Maine Agricultural Society, who, in 1803–1804, likewise published a series of agricultural papers and essays of much value.

The more important societies soon began the publication of information on agricultural subjects. As early as 1792, the New York society published a small quarto volume of its transactions. In 1797 the trustees of the Massachusetts society began the publication of pamphlets, or, as we now say, bulletins, on agricultural topics, which afterwards were developed into a regularly issued journal. The same year this society established "a regular library," having accumulated, "by gift and purchase, a considerable number of works on agriculture."

ESTABLISHMENT OF FAIRS FOR EDUCATIONAL PURPOSES.

Four years later (1801) a communication was presented to the trustees of the Massachusetts society which contained the germ of an educational movement on behalf of agriculture, destined to have an important influence on the improvement of the art in this country, especially down to the opening of the civil war. This was the suggestion that fairs should be held in May and October in Cambridge common and "small bounties given for certain articles." Nothing was immediately done to carry out this plan; but in 1804, Dr. Thornton, the first United States Commissioner of Patents, proposed that fairs should be held in the city of Washington on market days, after the English fashion. This idea was eagerly taken up by the citizens and municipal authorities, and the first fair was held in October of that year. It was such a decided success that two others were held in succeeding years, after which, however, they were discontinued. A great impetus seems to have been given to this movement by the enthusiastic labors of Elkanah Watson, of Massachusetts, who, beginning with an exhibition of two merino sheep on the public square at Pittsfield in 1807, soon developed the more elaborate and picturesque "cattle shows," which for many years were the popular rural festivals, especially in New England. Much interest also attaches to the "sheep shearings," the most famous of which was annually held for a dozen years, beginning with 1808, by George Washington Parke Custis, at "Arlington," his estate near Washington, on the Virginia bank of the Potomac. This was attended by throngs of prominent men, and had much social as well as agricultural importance. The interest in the movement for the promotion of agriculture awakened at the national capital is further shown by the organization in 1809 of the Columbian Agricultural Society, which was the foundation of the national organization finally formed in 1852. From 1809 to 1812, inclusive, this society held six fairs, at which cattle, woolen goods, cotton cloth, fancy work, clothing, bed linen, sewing thread, carpeting, rugs, dyes, etc., were exhibited.

THE BEGINNING OF AGRICULTURAL EDUCATION.

Washington's deep interest in measures for the advancement of agriculture is evidenced not only by his letters but by his message to Congress in 1796, in which he earnestly pleads for the establishment of a national board of agriculture. Congress, however, took no decisive action on this proposition.

Meanwhile definite efforts had been made to secure for agriculture a place in the school system of the country. From the Transactions of the New York Agricultural Society we learn "that the legislature by an act passed April 11, 1792, had granted the sum of L.750 (£1,500) for five years to the trustees of Columbia College for the purpose of endowing additional professorships, and that the trustees had instituted, among others, a professorship for natural history, chemistry, and agriculture, * * * and that lectures had been given upon the different parts of the course." Samuel L. Mitchill, M. D., LL. D., an active member of the society, was elected to this professorship, probably on the recommendation of Dr. Samuel Bard, another member, who chanced to be a trustee of Columbia College. How far agriculture was directly taught by Dr. Mitchill we do not know, but we have his assurance that in the course in botany which he gave "the physiology of plants, including their food, nourishment, growth, respiration, perspiration, germination, etc., is therefore particularly enlarged upon as connected with gardening and farming." He also wrote essays on the chemistry of manures.

In 1794 the Philadelphia society received the report of a committee in which the claims of education in agriculture through the establishment of professorships in the colleges, as well as the teaching of agriculture in the common schools, are urged upon the attention of the State legislature.

In 1801 the Massachusetts society subscribed $500 for the establishment of a professorship of natural history in Harvard College, and a committee was appointed to obtain subscriptions for the permanent endowment of this professorship and for the support of a botanic garden. This resulted in the election of William D. Peck, in 1804, to fill the new chair, and in the later establishment of the botanic garden.

"Just as the country was well started toward helpful discussions and improvements along agricultural lines," says Professor Babson, "the second war with England placed many hindrances in the way of further progress in this direction, and these hindrances were subsequently strengthened by the rapid growth of manufacturing facilities and wealth-seeking industries. The tendencies of the times were citywards, and the era of good feeling naturally became an era unfavorable for great agricultural advancement. Nevertheless, the farmers and their friends, clearly understanding the unsatisfactory state of affairs, did what they could in spite of the indifference of the general public regarding their efforts." The formation of agricultural societies was continued and their number rapidly increased. In South Carolina, for example, eleven societies were in existence by 1823. The movement for the establishment of a national board of agriculture was renewed in 1817 by the Berkshire Agricultural Society of Massachusetts, which presented a memorial to Congress on this subject. The bill which resulted from this effort was, however, defeated in the House of Representatives. The following year (1818) saw the establishment of the New York Horticultural Society, the first organization of its kind in the United States. The American Farmer, the first distinctively agricultural periodical in this country, was started in Baltimore in 1819, and was very shortly followed by The Plough Boy, published by "Henry Homespun, jr.," at Albany, N. Y. The first agricultural paper in New England was issued in 1822.

Books on agriculture began to come more frequently from the press; among the most characteristic of these were "The Farmer's Assistant, by John Nicholson, esq., published at Albany, N. Y., in 1814 [a second large edition in 1820], embracing every article relating to agriculture, arranged in alphabetical order;" "Nugæ Georgicæ" (Agricultural Trifles), by the Hon. William Johnson, senior vice-president of the Literary and Philosophical Society of Charleston, S. C., published in 1815, which is an "endeavor to sketch the outlines of a picture of the cares and amusements, the duties and employments, of the Carolina farmer;" "Arator," by John Taylor, an eminent statesman and agriculturist, published at Petersburg, Va., in 1818, and considered the forerunner of the American Farmer, which seems to have had a great influence on Virginia agriculture; "The Farmers' Library," by Leonard E. Lathrop, published at Rochester, N. Y., 1826–1828, "to explain some of the fundamental principles which relate to agricultural science."

Gradually there came into being a desire for more exact and fresh information regarding agricultural conditions and needs, as is evidenced by the action of the State of Massachusetts in 1837 in authorizing an agricultural survey of the State to "collect accurate information of the State and condition of its agriculture and every subject connected with it, point out the means of improvement, and make a detailed report thereof, with as much exactness as circumstances will admit."

Along with these general measures for the instruction of the farmer there went a series of efforts to develop agencies for direct school training in the science and practice of agriculture. In 1819 Simeon De Witt, surveyor-general of New York, published a pamphlet at Albany urging the foundation under State authority of "The Agricultural College of the State of New York," not so much "to give instruction to farmers as to make farmers from the other classes of society, which are stocked with such a superfluity of members that hordes of them must otherwise remain useless or worse than useless to the community." Two years later (1821) Robert Hallowell Gardiner, of Maine, obtained an annual grant of $1,000 from the State legislature to aid in maintaining an institution which was to give mechanics and farmers "such a scientific education as would enable them to become skilled in their professions." This institution was incorporated as the "Gardiner Lyceum;" a stone building was erected for its use, and students were first received January 1, 1823. Rev. Benjamin Hale, a former tutor in Bowdoin College and later (1827–1835) professor of chemistry in Dartmouth College, was the first president. The course of study at the lyceum was arranged for two years, and there were twenty students the first year. The courses may generally be described as a chemical and a mechanical one. There was a permanent professor of agriculture, a practical farm, and special short winter courses. The school kept up for many years, its numbers reaching at one time as high as fifty-three. It had a good library and collections. About the same time (1822) the agricultural society of Albemarle, Va., made an earnest but unsuccessful effort to raise funds for the establishment of a professorship of agriculture in the University of Virginia. Prominent in this movement was James Madison, then president of the society, and the following extract from the letter written over his signature to the other agricultural societies of the State is interesting as showing the interest manifested in chemistry as an aid to agriculture:

> This science is every day penetrating some of the hidden laws of nature and tracing the useful purposes to which they may be made subservient. Agriculture is a field on which it has already begun to shed its rays, and on which it promises to do much toward unveiling the processes of nature to which the principles of agriculture are related. The professional lectures on chemistry, which are to embrace those principles, could not fail to be auxiliary to a professorship having lessons on agriculture for its essential charge.

In 1825 a plan for an agricultural college was submitted to the legislature of Massachusetts and discussed there and in the New England Farmer and other papers for some time. It was to be much like other colleges of the time, with the addition of courses in agriculture and mechanic arts, provided with a farm and shops. No immediate results followed this agitation. An agricultural school established at Derby, Conn., in 1826, proved immediately successful, and was obliged to increase its accommodations for students. Another phase of this movement is seen in the "manual-labor" schools organized in a number of places in New York between 1825 and 1840. They were founded for the purpose of enabling needy students to secure an education by devoting a part of their time to actual labor in the fields or shops, which should also constitute a part of their education. Though somewhat enthusiastically undertaken, this plan soon proved a total failure. The same idea has, however, been revived from time to time by those who are not aware of the teachings of experience in this direction.

Agitation on behalf of agricultural education grew more active, and between 1845 and 1850 a number of agricultural schools were established by private enterprise in New York and Connecticut, some of which met with considerable success for quite a period. In 1846 John P. Norton was appointed professor of agricultural chemistry and vegetable and animal physiology at Yale College, and the demand for teachers of agricultural chemistry had grown to be sufficient by 1848 to warrant the establishment of a course for their preparation at the same institution. In 1853 the New York legislature passed acts establishing a State agricultural college and an industrial school, to be known as "The People's College." These institutions, however, did not become firmly established. Agricultural colleges which have grown to be permanent and strong institutions were opened for students in Michigan in 1857 and in Pennsylvania and Maryland in 1859.

State agricultural colleges were incorporated in Iowa and Minnesota in 1858, and professorships of agriculture were established about this time in several literary colleges.

During the twenty years preceding 1860 the movement for the advancement of agriculture was greatly broadened and strengthened by organizations representing the different States. By the end of this period State agricultural or horticultural societies had been formed in Massachusetts, Connecticut, New York, Pennsylvania, Georgia, Ohio, Illinois, Michigan, Wisconsin, and Indiana, and State boards of agriculture in Indiana, Massachusetts, and Maine.

ORGANIZATION OF A NATIONAL AGRICULTURAL SOCIETY.

In 1841 an attempt was made to organize a national agricultural society at Washington and to secure the fund left by Hugh Smithson for the maintenance of such an organization, but this resulted in failure, owing to the decision to use this fund for the establishment of the Smithsonian Institution. But eleven years later (1852), at a convention called by twelve State agricultural associations, the United States Agricultural Society was organized. Professor Babson thus writes of the work of this society:

> The annual meetings practically accomplished the results which would have been obtained by a national board of agriculture, as suggested by General Washington and subsequently by the Berkshire Society in Massachusetts. The meetings were prolific of important reports, investigations, and, best of all, discussions. Association and communication of thoughts and interests were the secrets of its

great work, and up to the beginning of the civil war it was essentially the center of the agricultural interests of the country. At each of its meetings it urged the establishment of a Department of Agriculture, until finally the result was attained. It published a record of its transactions and also a periodical with "reports of the annual meetings, exhibitions, and operations of the society, with a general statement of the position of agricultural affairs at the metropolis and reports of the operations of State boards and societies and agricultural colleges and of all legislative recognition of the predominant interests of the country.

ORIGIN OF THE UNITED STATES DEPARTMENT OF AGRICULTURE.

Congress first took an active interest in the promotion of agriculture in 1839, when, on the recommendation of Hon. Henry L. Ellsworth, Commissioner of Patents, an appropriation of $1,000 was made for the "collection of agricultural statistics, investigation for promoting agricultural and rural economy, and the procurement of cuttings and seeds for gratuitous distribution among the farmers." This work was gradually developed; investigations in entomology, chemistry, and botany were provided for by 1855, and the way was thus opened for the establishment of the United States Department of Agriculture in 1862. It is sufficient to call attention here to the fact that the Department has taken an active part in movements for the technical education of farmers, and has directly disseminated a very large amount of useful information on agricultural subjects, much of which has been obtained through its own investigations and scientific researches.[1]

DEVELOPMENT OF SCIENTIFIC AND TECHNICAL EDUCATION.

In the foregoing brief outline of the main facts attending the development of the movement for the dissemination of agricultural information and the organization of institutions for agricultural education in this country during the first half of the nineteenth century, it has been shown that there was a gradual broadening and deepening of the public demand for national and State action in this direction. This movement on behalf of agriculture was, however, only one phase of a general intellectual and industrial advance, which widely affected public sentiment in the United States, as well as in the rest of the civilized world. The physical sciences, especially chemistry and geology, were developed with remarkable rapidity during this period and were revolutionizing some of the arts and producing great changes in agriculture. The development of steam transportation, the invention of the telegraph, the multiplication of machinery, the discovery of gold in California, the emigration of European people to this country, and the rapid spread of population west of the Alleghenies, all these things, scientific, industrial, and political, had brought about a general recognition of the fact that the old order of

[1] The work of the Department of Agriculture is fairly presented in the various papers in this Yearbook, each one of which discusses some phase of scientific or economic investigation in relation to agriculture in which the Department has taken part.—Ed.

things was passing away and awakened a great desire for new information and new training. The sciences found their way into the curricula of academies and colleges, slowly at first, but with accelerated rapidity as the years passed and competent teachers increased in number. The friends of the old classical education were, however, powerful enough to make progress in this direction altogether too slow to satisfy those who had enthusiastically adopted new views of education, and prevented anything like a symmetrical reorganization of courses of study so as to fully recognize the claims of the natural sciences to be a component part of the system of higher education. Moreover, institutions founded on literary and philosophical lines were not able to bring themselves at that period to favor the introduction of courses of instruction based on the needs of the students desiring to perfect themselves in the technical principles and practice of the arts and industries. Thus arose a demand for a new class of institutions which should be entirely devoted to scientific and technical education.

Some efforts were made to supply this demand by private enterprise, but the people, who by this time had become accustomed to the support of public schools for elementary education, quickly saw the advantage which would flow from the organization and maintenance of these new institutions under State or national patronage, and readily seconded the efforts of their leaders to secure recognition for the movement in State legislatures and in Congress. In their enthusiasm for the direct application of science to the arts, the people and educators alike oftentimes attempted to found agricultural and other technical schools on too narrow a basis, making them manual-labor or trade schools in which the fundamental principles of sound pedagogy were almost entirely neglected. There were, therefore, many failures and much confusion of thought as to the best curricula for scientific and technical schools. It was, in fact, too early in the history of the "new education" to expect clear definition of aim and purpose or the perfection of details of instruction. There must necessarily be many experiments and numerous failures before a system of technical education suited to the complex needs of modern industries and the American continent and people could be even fairly well formulated.

THE MORRILL ACT OF 1862.

It was fortunate that at this juncture the national leader who sought to crystallize the growing demand of the people for technical education into an act of Congress, endowing colleges for this purpose in every State of the Union, was a man of broad views and large practical sense, willing to draw his measure on comprehensive lines and leave future experience to work out successful results, even through many tribulations and great risk of fatal bungling. This man was Justin L. Morrill, of Vermont, who, having by his own efforts risen to success in mercantile and agricultural pursuits in the midst of a hard-working but intelligent and progressive community, had come to Congress in the prime of life with an open mind toward every measure which promised to widen the opportunities and increase the welfare of the masses and had in it the promise of attaining practical results by businesslike methods.

On December 14, 1857, Mr. Morrill introduced into the House of Representatives a bill "donating public lands to the several States and Territories which may provide colleges for the benefit of agriculture and mechanic arts," and granting 2,000 acres of land for each Member of Congress for this purpose. The bill was referred to the Committee on Public Lands, who brought in an adverse report April 15, 1858. Nevertheless, in the next session of Congress the bill passed both Houses, but was vetoed by President Buchanan. In spite of this defeat and the legislative disturbances caused by the opening of the great civil war, Mr. Morrill persisted in his efforts to secure national aid for industrial education, and on December 16, 1861, introduced an amended bill. A similar measure was introduced in the Senate May 2, 1862, by Benjamin Wade, of Ohio. On May 28 the bill was reported adversely in the House by the Committee on Public Lands, but was passed by the Senate June 10, and nine days later by the House. President Lincoln approved the bill July 2, 1862.

The provisions of the Morrill Act.

As finally passed the Morrill Act of 1862 was a comprehensive measure, providing for "the endowment, support, and maintenance of at least one college [in each State] where the leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to agriculture and the mechanic arts, in such manner as the legislatures of the States may respectively prescribe, in order to promote the liberal and practical education of the industrial classes in the several pursuits and professions in life." For these purposes there was granted to the several States 30,000 acres of public land for each Senator and Representative in Congress, the entire proceeds of the sale of which must be so invested as to constitute a perpetual fund yielding not less than 5 per cent interest, "the capital of which shall remain forever undiminished (except so far as may be provided in section 5 of this act) and the interest of which shall be inviolably appropriated by each State which may take and claim the benefit of this act." The exception to this requirement is "that a sum, not exceeding 10 per cent upon the amount received by any State under the provisions of this act, may be expended for the purchase of lands for sites or experimental farms." "No portion of said fund, nor the interest thereon, shall be applied, directly or indirectly, under any pretense whatever, to the purchase, erection, preservation, or repair of any building or buildings." The colleges were to be entirely under the control of the States, and in fact could not be established or maintained unless the States provided buildings. It is obvious, therefore, that in this, as in other acts passed by Congress to aid the institutions, the national funds were intended to be only partial endowments, which were to be supplemented by the States in any way and to any extent required by their growing necessities.

Land donated and number of institutions benefited under the Morrill Act.

The amount of land actually obtained under this act ranged from 24,000 acres for Alabama to 990,000 acres for New York. Unwise management in many States caused the premature sales of the lands at a period when large grants to railroads and the opening of vast areas to settlers free of cost had made the college-land scrip almost worthless. The general result was that many States received small advantage from the land grant, the income of which in some cases was not sufficient to properly maintain even a single department of a college. In a few States, like New York and Michigan, where the number of acres received was large and the sale of the land was skillfully made, large funds were obtained and strong institutions were established. The total fund received from this land amounts to over $10,000,000, and 1,240,000 acres still remain to be sold.

Twenty-five years after the passage of the land-grant act of 1862 the United States Bureau of Education reported that forty-eight institutions had shared in the benefits of the act.

In thirteen States the grant was made over to universities or colleges already existing, and has served to establish or augment the funds of courses, departments, or schools of applied science in the same. In the twenty-five remaining States the fund has served as the chief source of endowment for new institutions, or as the nucleus around which have collected additional funds, in several cases far exceeding the amount received from the national grant.

Early relations of institutions benefited by the Morrill Act to agricultural education.

In discussing the early relations to agricultural education of the institutions which received the benefit of the Morrill Act, it is difficult to make any general statements which will not be misleading. The broad provisions of the act; the widely varying amounts of money obtained from the sales of the land; the vagueness and incompleteness of the system of scientific and technical education in all lines, and especially in agriculture; the indifference of the farmers to agricultural education and their demand for the training of their children in other directions; the conservatism of the public and of educators regarding changes in long-established courses of study; the claims of established institutions to share in the benefits of this act; the no less urgent claims of the promoters of new colleges; the local, political, and denominational influences; the industrial conditions in this country—these are some of the factors which contributed to produce the greatest variety in the institutions organized under this act and to vary in still larger measure the attention which they gave to education in agriculture. While it is true that the sciences had begun to make their way into schools and colleges in this country prior to 1862, it is also the fact that for the most part the American colleges were institutions maintaining a single classical course, which must be rigidly followed by all students desiring to graduate. Courses of study in the sciences were yet to be developed, teachers in these branches were to be trained, and the system of elective studies was to be organized, while graduate courses of instruction and research were hardly thought of. Technical and industrial education necessarily had to wait until instruction in the sciences, on which such training must be based, had been put on something like a sound basis and had secured a reasonable supply of well-trained teachers and at least fairly adequate buildings, apparatus, text-books, and other equipment.

Even in the strongest institutions established under the Morrill Act of 1862, for many years most of the State and national funds obtained for their maintenance were wisely expended in building up sound education in the natural sciences. In this way only could they lay strong and deep foundations on which to rest a substantial superstructure of technical education when the times were ripe for its erection. Speaking broadly, the chief function of the land-grant institutions during the first quarter century of their existence was to aid in the establishment and perfecting of instruction in the natural sciences throughout the country. In doing this they did a great work for agriculture and the other industries by giving free tuition to thousands of students drawn from the industrial classes, who have since used their trained talents for the development of our industries by utilizing scientific facts and principles for their advancement. But more than this, these colleges at once begun, in greater or less degree, the building up of technical courses in agriculture and the development of agricultural research along scientific lines. If the farmers had responded to the efforts of the colleges in this direction many more of their children might have received direct, even if imperfect, instruction in the theory and practice of agriculture, and the movement for the development of such instruction might have been greatly accelerated. Amid many discouragements within and without, the colleges for technical education in agriculture gradually made their way, and the various lines of endeavor now hopefully expanding had their foundations surely laid in the institutions established under the Morrill Act of 1862. A new and peculiarly American principle had been introduced into our educational system by this great act, which is well set forth in the memorial address of President Buckham, of the University of Vermont, on Senator Morrill before the Association of American Agricultural Colleges and Experiment Stations at San Francisco, July 6, 1899, in the following words:

What Mr. Morrill meant, as his many speeches show, was that the liberal education of the industrial classes should make their pursuits professions, and should liberalize the industries and arts of life. This is really the central and controlling thought of the whole scheme—to bring the light of learning and the aid of science to bear upon those pursuits and callings which, hitherto regarded as illiberal and wearing the badge of inferiority, would thus be lifted to the plane with the other professions, and confer equal respectability upon their members.

DEVELOPMENT OF FARMERS' INSTITUTES.

Meetings which the general public and especially farmers were invited to attend were held at a comparatively early day under the auspices of the local or State agricultural societies. Out of these meetings grew a more or less clearly defined institution for the technical education of the adult farmer, now known as the farmers' institute. While the character of the institutes is such as to make it impracticable to assign any definite date as the time of differentiation from other farmers' assemblies, yet the period following the organization of the agricultural colleges under the Morrill Act of 1862 seems to have been the time when the farmers' institutes took a distinct form, and under that name began to receive the patronage of the States. Thus, in 1862 the Massachusetts State Board of Agriculture held a public meeting of four days' duration, and in 1866 the Connecticut State Board of Agriculture held its first farmers' convention for lectures and discussion. In 1870 the newly organized State Board of Agriculture of New Hampshire began a series of farmers' meetings, and the following year Vermont followed this example. The same year the Massachusetts board requested the twenty-nine agricultural societies of the State to organize annual meetings, to be denominated the "Farmers' Institutes of Massachusetts," and several societies began at once to hold such meetings. About the same time institutes were inaugurated in Kansas, and a little later in Michigan, by the agricultural colleges of these States. Other States joined the movement, and legislatures began to make appropriations to maintain the institutes.

In 1885, when the board of regents of the University of Wisconsin organized a course of institutes, a special officer, called the superintendent of farmers' institutes, was appointed to plan and manage them, and this arrangement was afterwards confirmed by the State. While the institutes are carried on under varied auspices in the different sections of the country, the character of the meetings themselves has been essentially the same wherever they have been held. They are usually held during the winter months, but in some cases at other seasons of the year, and as a rule continue from two to four days. "The programmes are planned to promote the interchange of ideas, a full and free discussion being sought upon topics introduced in an address or paper by some specialist." Officers of agricultural colleges and experiment stations, and other experts, together with successful farmers who have attained more than local reputations, are usually selected as institute workers by the officers who have charge of the system of institutes for the State, or they may be chosen by the local authorities from lists prepared by the central bureau. There is very often a local committee, which provides local speakers, music, literary, and other general exercises, and arranges for the place of meeting, refreshments, and advertising.

All persons in attendance, the humblest as well as the most prominent, are urged to ask questions upon points suggested in the address and to present related facts gained from personal experience. A "question box" is frequently made use of, answers being given by the conductor of the institute or by some one specially fitted to supply the information asked. For the evening sessions the usual plan is to have a popular lecture upon some subject of general agricultural interest. This address is made somewhat more elaborate and complete than those of the day sessions and less opportunity is given for discussions.

ASSOCIATION OF AMERICAN AGRICULTURAL COLLEGES AND EXPERIMENT STATIONS.

The need of coming together for conference was definitely recognized by the institutions organized under the Morrill Act of 1862 as early as 1883, when a convention of delegates from the agricultural colleges met at Washington, D. C., for the special purpose of promoting the establishment of experiment stations in connection with these colleges. On July 8, 1885, a convention of agricultural colleges and experiment stations (a number of which had by this time been organized by the States as separate institutions) met at the Department of Agriculture in Washington in response to a call issued by the then Commissioner of Agriculture, Norman J. Colman, of Missouri, and on October 18, 1887, at a second convention in the same city a permanent organization was effected, under the name of "The Association of American Agricultural Colleges and Experiment Stations." This association was at first very largely interested in the establishment and development of the agricultural experiment stations, but from the outset gave considerable attention to the general interests of the land-grant colleges, and from time to time has made this feature of its work more prominent. The work of the association is, in fact, much broader than its name would indicate. The institutions comprising it cover a very wide range of educational work, several of them being great universities, numbering their students by the thousand and their instructors and courses of study by the hundred. The association has, however, always been active and earnest in its efforts to promote agricultural education, and has been an influential factor in aiding the advancement of such education throughout the country.

THE AGRICULTURAL EXPERIMENT STATIONS.

Even before the passage of the Morrill Act of 1862 the agricultural schools and colleges established under private or State auspices began experimental inquiries on agricultural problems, and the institutions which received the benefits of that act took up the same work in a larger way. In 1875 a regularly organized experiment station was established by the State of Connecticut. Other States followed this example by establishing experiment stations either as separate institutions or in connection with the land-grant colleges. In 1887 Congress nationalized this movement by the passage of the Hatch Act, which provided for the establishment and maintenance of experiment stations as departments of the land-grant colleges in all the States and Territories. These institutions are in law and in fact integral parts of the higher institutions for education in agriculture, representing essentially the university side of such education, being set above the undergraduate departments of the colleges as organizations devoted to original research.[1] They are the fountain heads of agricultural knowledge, and the results of their work are more and more to form the basis of all instruction in agricultural science from the college down to the common school and out to the masses of workers on our farms. Already they have surpassed all other agencies in the dissemination of useful information among our farmers and have collected a fund of new knowledge which has radically changed the text-books and courses of instruction in agriculture in this country.

THE SECOND MORRILL ACT.

The establishment of the experiment stations greatly quickened the interest in agricultural education throughout the country. The demand for other forms of technical education had also grown apace. It became evident that the land-grant institutions in many States were unable to meet the calls made upon them to increase their faculties and facilities for technical education. There was increasing liberality on the part of the States toward these institutions, but the State appropriations were in many cases very inadequate. At this juncture Mr. Morrill came forward with a proposition to increase the endowment of the land-grant colleges out of the national funds arising from the sale of public lands. His bill for this purpose passed both Houses of Congress and was approved by President Harrison August 30, 1890. This act provides for an annual appropriation, as follows:

> To each State and Territory for the more complete endowment and maintenance of colleges for the benefit of agriculture and the mechanic arts now established, or which may be hereafter established, in accordance with an act of Congress approved July second, eighteen hundred and sixty-two, the sum of fifteen thousand dollars for the year ending June thirtieth, eighteen hundred and ninety, and an annual increase of the amount of such appropriation thereafter for ten years by an additional sum of one thousand dollars over the preceding year, and the annual amount to be paid thereafter to each State and Territory shall be twenty-five thousand dollars, to be applied only to instruction in agriculture, the mechanic arts, the English language, and the various branches of mathematical, physical, natural, and economic science, with special reference to their applications in the industries of life, and to the facilities for such instruction.

[1] The history of experiment stations is given in a separate article in this Yearbook.—Ed.

Provision is made for separate institutions for white and colored students in States which may desire to make such an arrangement. The Secretary of the Interior is charged with the administration of the law, and is given authority to withhold the appropriation to any State or Territory for cause, subject to an appeal to Congress.

DEVELOPMENT OF COLLEGES OF AGRICULTURE DURING THE CLOSING DECADE OF THE CENTURY.

The second Morrill Act has been of great benefit to agricultural education in this country. Many of the land-grant colleges which formerly had done little for their agricultural courses, either because of their limited funds or through lack of interest in the subject, were enabled to put them on a respectable footing, and were aroused to renewed efforts to make them substantial and attractive. The State legislatures were also more easily led to make liberal appropriations for buildings and facilities for instruction in these institutions, now that their value and importance had been recognized in such a notable manner by Congress. The friends of agricultural education became more active in urging their claims upon faculties, boards of management, and legislatures, and met with increasing success in securing for agriculture a larger recognition in the college curriculum. The establishment of the experiment stations had attached to these colleges a much larger and stronger body of men whose prime interest was on the side of agriculture, and the increased financial revenues of the colleges made it possible to utilize the services of many more instructors in agricultural subjects. The ten years which have elapsed since the passage of the second Morrill Act have therefore been marked by the development of agricultural education along a number of new lines. They have been in great measure years of preparation, the result of which will be realized in the coming century. Many plans for advancement in agricultural education have been proposed, and many tentative propositions for the improvement of the working scheme for such education have been suggested. Here and there new enterprises in this direction have been very successful; and what is perhaps the most important thing, there has been a growing hopefulness that before long there will be such a system of education in agriculture in this country as will not only supply a sufficient number of well-trained leaders in agricultural progress, but will also spread abroad among the masses of our rural population definite and useful information regarding the principles and the best practice of agriculture.

The rapid advance in the number and extent of scientific investigations along agricultural lines has revealed to scientists, schoolmen, and farmers alike something of the breadth and depth of the subject of agriculture, whether considered as a science or as an art. This has led to a recognition of the fact that no single scheme of technical education in agriculture will meet the needs of our times. Two general results of vital importance have followed: First, the subject of agriculture has been divided into an increasing number of specialties, and each year more men have devoted themselves to the study and teaching of some one branch of agriculture; and, second, instead of being satisfied with maintaining one general curriculum in agriculture, covering the usual period of four years, the colleges have more and more endeavored to diversify the courses in agriculture and adapt them to the needs of different classes of students. Agriculture, considered as a subject of education, has felt the same influences which in other subjects have produced such wide specialization and such varied courses of instruction. The movement, as related to agriculture, has not, however, proceeded so far as in the case of other subjects, and the century will close without witnessing the thorough organization of agricultural education in this country along permanent lines.

In the older curriculum the teaching of agriculture was for the most part divided between the agricultural chemist, who dealt especially with matters relating to soils, fertilizers, and the principles of feeding and dairying, and the so-called agriculturist, who usually was expected to cover the round of farm practice. Instruction regarding the diseases of animals was at an early day given a distinct place under the name of veterinary science. The diseases of plants were turned over to the botanist or horticulturist, and insect pests to the zoologist or entomologist. In most institutions horticulture was clearly divided from agriculture. The new movement for the division of the general subject of agriculture in the colleges of this country may perhaps be said to have begun with the separation of dairying as a distinct branch of instruction. This was in large measure due to the revolution in the methods of dairying, caused by the investigations of the experiment stations, which led to the multiplication of creameries and cheese factories. The technology of dairying on both its scientific and practical sides became a large and distinct subject in the minds of the farmers and the college authorities. This made it easy to assign dairying a separate place in the curriculum, and to provide one or more special teachers for this branch of agriculture. The science of animal production (zootechny) about this time assumed large proportions, and as means increased it was found desirable to have at least one teacher in the college faculty who should devote himself exclusively to this subject. But this has already proved too large a burden for any one man to carry to the complete satisfaction of his students, and a few of our strongest colleges have subdivided this subject. More recently studies in agricultural physics, especially as related to soils, have been so far developed and systematized that special laboratories and teachers for this branch of agriculture have been found very desirable wherever the resources of the institution would permit. By the changes above indicated a place has been made for the more systematic organization of instruction in plant production (agronomy) as a distinct college department, and this has been done at a number of colleges. Thus far rural engineering and rural economics, including the history of agriculture, have been incidental features of our college courses, and have been assigned to teachers whose main work has been in other lines.

The specialization of work and the consequent increase in number of instructors have made it possible to more efficiently organize various forms of short and special courses in agricultural subjects. As long as the four years' course in agriculture was a simple and rigid curriculum, the attempt to introduce a shorter course on the same general plan, but more superficial and imperfect in detail, did not prove generally successful. It was difficult for the outside public to distinguish between the two courses, which led the long-course students to think that their standing as college men was imperiled by misunderstanding regarding their status as compared with that of the short-course students. While the pedagogical character of the long course was as a rule nondescript, that of the short course was still more so. So general was the dissatisfaction with these earlier short courses that at one time it seemed as if the colleges would wholly abandon them; but now they are being revived in new and much more satisfactory forms. When the short course covers the general subject of agriculture, a better selection of topics is made and the student receives from different specialists more definite information and a more intense stimulus to pursue the subjects further on his own account. But the greatest success has been attained with the short courses which have included only a limited number of agricultural topics and afforded more precise and extended practical instruction along one or two lines. This has been particularly true of the short courses in dairying, in which it has been found practicable to unite with the theoretic instruction sufficient practice to enable the student taking such a course to become an efficient worker in the farm dairy or the creamery or cheese factory. The diversification of the four years' course in agriculture, through the introduction of the elective system, and the elevation of this course to a grade more nearly approximating other courses for which the bachelor's degree is given, have in large measure done away with the student's opposition to the obviously lower courses occupying a shorter time. The present tendency is toward the organization of the shorter courses as schools distinct from the college departments, though belonging to the same institution. These may be special schools, as in dairying, or general agricultural schools of secondary grade.

THE IMPROVEMENT OF COLLEGE COURSES IN AGRICULTURE.

Courses in agriculture in our colleges have developed very largely according to the views of individual teachers or the supposed or real necessities of the institutions, owing to their local environment; but with the establishment of courses in the natural sciences on a sounder pedagogical basis and the rapid enlargement of the courses for instruction in the theory and practice of agriculture, there has been increasing realization of the desirability of systematizing courses in agriculture according to modern pedagogical methods.

Realizing this need, the Association of American Agricultural Colleges and Experiment Stations, at its convention in 1894, appointed a committee on entrance requirements, courses of study, and degrees, whose final report, presented two years later, was adopted. This report recommended as a standard series of entrance requirements for college courses the following subjects: (1) Physical geography; (2) United States history; (3) arithmetic, including the metric system; (4) algebra to quadratics; (5) English grammar and composition, together with the English requirements of the New England Association of Colleges and Preparatory Schools; (6) ancient, general, or English history. Recognizing the fact that a considerable number of the land-grant colleges were not in a position to immediately insist on these entrance requirements, the committee suggested that all should unite in requiring the first five subjects as a minimum for admission to their lowest collegiate class. For all four years' courses, leading to a bachelor's degree, it was urged that the colleges should require the following general studies: (1) Mathematics, at least through algebra, geometry, and trigonometry; (2) physics and chemistry, with laboratory work in each; (3) English language and literature; (4) other languages (one at least modern); (5) mental science and logic or moral science; (6) constitutional law; (7) social, political, or economic science.

In 1895 the association appointed a standing committee on methods of teaching agriculture, which has thus far presented four reports of progress. Taking up the work where the committee on entrance requirements left it, this committee first suggested that the following subjects be added to the general subjects named above to complete the four years' course in agriculture leading to the degree of bachelor of science: (1) Agriculture; (2) horticulture and forestry; (3) veterinary science, including anatomy; (4) agricultural chemistry; (5) botany, including vegetable physiology and pathology; (6) zoology, including entomology; (7) physiology; (8) geology; (9) meteorology; and, (10) drawing. It then proceeded to divide the subject of agriculture as follows: (1) Agronomy, or plant production; (2) zootechny, or animal industry; (3) agrotechny, or agricultural technology; (4) rural engineering, or farm mechanics; and, (5) rural economics, or farm management. It has since presented somewhat detailed outlines of courses in agronomy and zootechny. It is believed that the work of these committees is chiefly significant as indicative of an earnest and widespread movement among the colleges of agriculture to systematize and improve the courses in agriculture. The committees have simply endeavored to give form to a general desire for the elevation of college courses in agriculture to the same level as other college courses and the specialization of the instruction in agriculture as is being done everywhere in regard to other subjects included in the modern scheme of liberal education.

ORGANIZATION OF SECONDARY SCHOOLS OF AGRICULTURE.

The improvement of the college courses in agriculture has been accompanied by efforts to provide courses which are distinctly of secondary grade. It has become clear that the college courses will meet the needs of only a comparatively small number of students from the farms, and that a large part of the college graduates will find their most suitable employment as investigators, teachers, journalists, or workers in those industries more or less closely connected with agriculture in which knowledge of the science as well as the practice of agriculture is requisite. Instruction in agriculture of the secondary grade has for some years been given in connection with the other industrial courses at the Hampton Institute, in Virginia, and more recently at the Tuskegee Institute, in Alabama, and some other similar schools for colored students. In 1895 a secondary school of agriculture was organized at the University of Minnesota, with a course of study and faculty clearly differentiated from those of the college of agriculture. This school has been largely attended and has proved quite successful. For the past two years girls as well as boys have been admitted to this school, and special provision has been made for their residence at the institution. A similar school has recently been opened at the University of Nebraska. The State of Alabama has for a few years past made provision for the maintenance of schools of agriculture of secondary grade in each of the nine Congressional districts of the State. The Baron de Hirsch Agricultural and Industrial School, at Woodbine, N. J., regularly opened for students in 1894, provides general and agricultural education of the secondary grade, combined with a large amount of practical farming and horticulture, to a limited number of boys and girls. A similar school for boys is the National Farm School at Doylestown, Pa., opened for students in 1897.

EFFORTS TO INTRODUCE AGRICULTURE INTO THE COMMON SCHOOLS.

Throughout the century efforts have been made from time to time to introduce instruction in agriculture into the common schools. These efforts have uniformly failed, partly because too much was attempted, and partly because the condition of the schools did not permit of changes in their curriculum in this direction. Thus far our common schools, especially in the rural districts, have done very little toward introducing even elementary lessons on natural objects, and much less the systematic study of the elements of any natural science. The organization of anything like a complete system of common schools over vast areas of a new territory with a rapidly growing population has been a gigantic task, and until recently there has been little opportunity for the consideration of measures for the improvement of courses of instruction in our rural schools. We have been justly proud of the wide and free dissemination of elementary education in this country, but we have hardly yet come to realize how much needs to be done to put these schools on the most efficient basis. For some years it has been apparent to close students of the rural schools that the most practicable step toward the introduction of instruction which would directly bear on agriculture was to secure some definite training of the pupil's powers of observation through exercises based on natural objects. A very hopeful beginning of a movement in this direction, which now promises to become widespread, was made in 1894 in connection with the College of Agriculture of Cornell University, under the leadership of Prof. L. H. Bailey.

By visiting the rural schools and giving sample lessons, the officers in charge of this work ascertained the needs and requirements of these schools as regards nature study and secured the interest and cooperation of a considerable number of school officers and teachers in a comparatively short time. To show the teachers more definitely how nature study may be presented to their pupils, a series of leaflets was begun, which were distributed throughout the State wherever teachers showed an interest in the movement. The plan proved at once successful, and means for its extension have been increased by succeeding legislatures. A corps of instructors have been employed in canvassing the State, and these have been aided by special teachers from time to time as occasion requires. These instructors meet the teachers of the schools in the presence of their pupils and at teachers' meetings for the purpose of illustrating methods for teaching nature studies. The leaflets serve as texts for the subjects taught. Very naturally, many of these leaflets are on subjects directly relating to agriculture, such as cultivated plants, fruits, weeds, and insects. It has been impracticable, even if it were at all desirable, to confine this movement to the rural schools, for the city teachers, who had in many cases begun nature teaching in one form or another, have been very eager to receive and utilize the leaflets and other special instruction on nature teaching emanating from Cornell University. It is reported that 25,000 teachers in New York State alone have received some instruction in this way, and the leaflets, being sold, are widely disseminated in other States. Some of the other colleges of agriculture, notably in Indiana, Missouri, Rhode Island, and Pennsylvania, are taking up this work, and plans for the introduction or more effective use of nature study in the common schools are being made in a number of States.

DEVELOPMENT OF UNIVERSITY EXTENSION IN AGRICULTURE.

Other forms of university-extension work in agriculture are being actively pushed by the agricultural colleges. Allusion has already been made to the work of these institutions in connection with the farmers' institutes. This work has been greatly developed since the establishment of the experiment stations. In one sense the immense amount of literature on agricultural subjects disseminated by the experiment stations and this Department form the most important and successful university-extension work thus far carried on in this country.

FEATURES OF THE EXTENSION WORK.

An interesting feature of this movement was inaugurated in a definite way by the State College of Pennsylvania in 1892, under the title "Chautauqua course of home reading in agriculture." The college provided a list of books and offered examinations on the subjects read. It was soon found desirable to help the readers over difficulties by correspondence. When the lack of suitable books for such a course became apparent, the college undertook to send out printed lessons and questions on particular subjects treated in the books, which should guide the readers to an intelligent use of the books, bring out their important points, and extend and illustrate the information which they contained. This plan proved highly successful, and the number of subjects on which lessons were thus prepared was extended until during the past year five courses, each comprising seven subjects, or books, were offered. On March 1, 1899, there were 3,416 readers enrolled, of whom 460 received systematic instruction by means of the lessons. There were readers in most of the States and some in foreign countries. This work of the college has outgrown the resources which can be devoted to its maintenance, and of late no special effort has been made to increase the enrollment. Farmers' reading courses have since been undertaken in various forms by the agricultural colleges in Michigan, New Hampshire, Connecticut, West Virginia, South Dakota, and New York.

In New York the reading courses form part of a more elaborate scheme of university extension than exists elsewhere in this country, one feature of which is the nature teaching already referred to. Here the course began with horticulture, but has been extended to include general agriculture. In its present form the New York plan is to send the farmer short, specially prepared lessons, with questions on a few topics, and to organize reading clubs; these clubs are visited by lecturers and inspectors, who give information and help to keep up the organization and enthusiasm. Last year 8,600 readers were enrolled, of whom over 8,000 were residents of New York. Another feature of the New York university-extension work is the itinerant school, in which special topics in horticulture or agriculture are taught for a few days by experts, thus imparting more definite and extended information than is possible in the single lectures at farmers' institutes.

Cooperative experiments, in which farmers in different localities have participated, have been made in Connecticut and other States almost from the beginning of the experiment-station enterprise. More attention is now being given to perfecting the plans and records of these experiments, and it is quite generally recognized that they are chiefly valuable as educational agencies. In New York this work has been joined with the general plan for university extension, in charge of the college of agriculture of Cornell University, and liberal appropriations have made it possible to carry on hundreds of simple experiments throughout the State.

Now that the educational world has become fairly awake to the comprehensive mission of the teacher, it sees that the set institutions of learning are not simply to do what they can for the youth who happen to come within their halls, but that they are rather to be the centers of light and inspiration to all the community about them. It is their business to go out and instruct men wherever they can find them, as well as to offer any proper inducement for pupils to come into their class rooms, because there can be found what is suited to their varied needs as regards both culture of body and mind and training for the life's work. Standards of acquirement there must be, and these have been made more thorough and exacting. Instruction must conform to sound pedagogical principles, and more attention is being devoted to studies of the mind of the pupil as related to his acquisition of knowledge. To do his best work the teacher must have aptitude and general and special training beyond what has hitherto been thought necessary. But after all the school must take the pupil where it can find him and do for him the best it can, considering chiefly his status and environment. It is the recognition of this fundamental principle, partial though the recognition has been thus far, which is producing the most profound change in the work and spirit of our institutions for education in agriculture, as it is also in other educational institutions everywhere.

AMERICAN BOOKS ON THE SCIENCE AND PRACTICE OF AGRICULTURE.

For many years one of the serious hindrances to the success of education in agriculture in the schools or among the farmers was the lack of good books on agriculture setting forth the facts and principles of agricultural science and practice as related to conditions of farming in the United States; but since the establishment of the experiment stations, and especially within the past few years, there has been a great increase in the number of books which are useful for the education of our agricultural people along the lines of their art. Much attention is being given to the preparation of books which may serve as works of reference or as text-books in different grades of agricultural instruction. The publications of the stations and of the Department in large measure supply the materials for these books, and they are written from an American standpoint. There is already a healthful competition in the production of books best adapted to special purposes of agricultural education, and thus the way is being prepared for the more general and satisfactory diffusion of such education in the twentieth century.

DEVELOPMENT OF GENERAL AGENCIES FOR THE EDUCATION OF FARMERS.

The second half of the nineteenth century has witnessed a great awakening of the farmers of this country to their educational needs and opportunities. This has led to the broadening of the work and influence of general agencies for their education. The State and local societies have been supplemented by great national organizations, such as the Farmers' Alliance and the Patrons of Husbandry (granges), which, besides doing a great deal for the promotion of their general welfare, have done much to quicken the desire of multitudes of farmers for definite education in matters relating to their art. That portion of the newspaper press which is wholly or partially agricultural has been more active and far-reaching than ever before in its efforts to disseminate useful information among the rural masses. State departments and other agencies for aiding the farmer to acquire knowledge along agricultural lines have been greatly strengthened. The limits of this article will forbid anything more than the mere mention of the origin and usefulness of these general agencies for agricultural education. In considering in any broad way the institutions for the farmers' education which now exist in this country, great credit must be given to those organizations which, though established for more general purposes, have exerted their influence to arouse the farmer to see the need of progress and enlightenment, and which have labored earnestly for the establishment and maintenance of institutions definitely organized for technical education in agriculture. Without the movement for the farmers' uplifting, begun and fostered by those general agencies, the schools and colleges of agriculture could not have reached their present promising condition.

THE AMERICAN SYSTEM FOR AGRICULTURAL EDUCATION IN THE YEAR 1900.

Without taking into account the general educational agencies just referred to, the American system for agricultural education as it exists at the close of the nineteenth century comprises a number of important branches whose functions may be more or less clearly differentiated.

DEPARTMENTS OF ORIGINAL RESEARCH AND GRADUATE STUDY IN AGRICULTURE.

At the head of this system stand the Department of Agriculture and the agricultural experiment stations now in operation in all the States and Territories chiefly as departments of the land-grant colleges. These constitute very largely the university, or graduate branch of agricultural education in this country, having for their chief functions the discovery and dissemination of new truths regarding the theory and practice of agriculture. Organized primarily with reference to research, both the Department and the stations to a considerable extent directly promote agricultural education, in the technical sense, by giving instruction to students. This is done by opening their laboratories to assistants who participate in research work while continuing their studies, or by imparting new inspiration and knowledge to students who become acquainted with the research work by indirect contact through residence at the institutions where it is being conducted. From time to time officers of the agricultural colleges and experiment stations come to work in the Department of Agriculture for a period, to carry on special investigations or to enlarge their knowledge of scientific facts and principles in special lines. In accordance with an arrangement recently made, a limited number of graduates of the land-grant colleges are admitted to the Department for advanced study and research. At the universities and colleges having courses in agriculture there are now a considerable number of persons pursuing graduate courses in agricultural subjects. This has for the most part been made possible by the establishment of the experiment stations as research departments of these institutions and the consequent employment of experts in different lines of agricultural science competent to give graduate instruction in their several specialties.

COLLEGE COURSES IN AGRICULTURE.

Under the provisions of the acts of Congress of July 2, 1862, and August 30, 1890 (Morrill acts), sixty-four colleges are in operation in the several States and Territories. Of these, about sixty institutions maintain courses in agriculture. In fourteen States separate institutions are maintained for white and colored students. These institutions are brought together to constitute a national system of higher education in the sciences and industries through the Association of American Agricultural Colleges and Experiment Stations, the Office of Experiment Stations of the Department of Agriculture, and the Bureau of Education of the Department of the Interior. The colleges of agriculture may be divided into three classes, according to the general differences in their organization: (1) Colleges having only courses in agriculture; (2) colleges having courses in agriculture along with those in a variety of subjects, including especially mechanic arts; and, (3) colleges (or schools or departments) of agriculture forming a part of universities. The only institution in this country which is simply an agricultural college is the Massachusetts Agricultural College.

Agricultural and mechanical colleges have been organized in Alabama, Colorado, Connecticut, Delaware, Florida, Iowa, Kansas, Kentucky, Maryland, Michigan, Mississippi, Montana, New Hampshire, New Jersey, New Mexico, North Carolina, North Dakota, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Carolina, South Dakota, Texas, Utah, Virginia, and Washington. Separate institutions of this class for colored students are maintained under the Morrill Act of 1890 in Alabama, Delaware, Florida, Mississippi, North Carolina, South Carolina, and Virginia. The instruction in these institutions has, however, very wisely been confined for the most part to courses below the college grade. A similar institution, maintained by private funds, is the well-known Tuskegee Industrial Institute, in Alabama.

Colleges of agriculture (or equivalent schools or departments) in universities are maintained with the aid of national funds in Arizona, Arkansas, California, Georgia, Idaho, Illinois, Indiana, Louisiana, Maine, Minnesota, Missouri, Nebraska, Nevada, New York, Ohio, Tennessee, Vermont, West Virginia, Wisconsin, and Wyoming. In Massachusetts, Harvard University has a school of agriculture known as Bussey Institution.

The college course in agriculture in most of these institutions extends through four years and leads to a bachelor's degree. The course varies considerably in different institutions as regards the requirements, both for admission and for graduation. In some cases students are admitted directly from the common schools, while in others the entrance requirements are on a level with those for admission to other college courses in high-grade colleges. The course at the Massachusetts Agricultural College may be taken as a type of a relatively high-grade college course in agriculture as given in American colleges. Candidates for admission must be at least 16 years old, and are required to pass examinations in English grammar, geography, United States history, physiology, physical geography, arithmetic, the metric system, algebra (through quadratics), geometry (two books), and civil government. The student is required to follow a definitely prescribed curriculum during three years, and in the fourth and last year of the course he is allowed wide latitude of choice among numerous specialties, English and military science being the only required studies. In freshman year the following subjects are included in the course: Agriculture, botany, chemistry, algebra, geometry, bookkeeping, English, French, military tactics, and mechanical drawing; in sophomore year, agriculture, horticulture, botany, chemistry, anatomy and physiology, trigonometry, surveying, English, and mechanical drawing; in junior year, agriculture, horticulture, chemistry, zoology, entomology, physics, English (including rhetoric and literature); in senior year, together with the required English and military science, at least three elective studies must be taken, which may be selected from the following: Agriculture, botany, chemistry, entomology, veterinary science, civil engineering, analytical geometry, calculus, English, German, Latin, political economy, history, and farm law.

In these colleges, as a rule, ample provision is made for the teaching of the sciences related to agriculture. Horticulture, vegetable pathology, economic entomology, and veterinary science are commonly taught along with agriculture, but by separate instructors. An outline course in forestry is also often given. The subject of agriculture is not infrequently divided among two or more instructors. Matters relating to soils, fertilizers, and the composition of plants, dairy products, etc., are often taught under the head of agricultural chemistry. Agricultural physics, especially as relating to soils, has been recently made a separate department of instruction in a number of colleges. The theory and practice of dairying, animal husbandry, and plant production have, in some cases, each been assigned to different instructors. Here and there some branch of animal husbandry (as sheep raising) has been deemed sufficiently important to require a special teacher. In general, differentiation of subjects hitherto grouped together under the general term "agriculture" is more and more followed by the employment of specialists to teach in a limited field. Much greater attention is being given than formerly to the improvement of methods of teaching agricultural subjects. This is evidenced by the employment of more thoroughly trained teachers, by individual and associated efforts to define and arrange the topics of instruction in accordance with pedagogical principles, by the general adoption of the laboratory system as applied to the field, the plant house, and the barn, as well as to the buildings constructed with special reference to the peculiar needs of instruction in agricultural subjects.

The collection and devising of apparatus and illustrative material are being pushed with much enthusiasm and success. Wherever means will permit, and in an increasing number of institutions, the housing and equipment of the agricultural department will compare favorably with that of other departments. Along with the improvement of the college courses in agriculture has come the realization of the true function of these courses. It is now well understood that they are for the training of the leaders in agricultural progress and not for the general education of the agricultural masses. For this purpose they are to be made as thorough and complete internally and externally as the manifold needs of American agriculture for well-trained and intelligent leadership may require. Their success is to be judged by the same standard that is applied to other college courses, and the number of students is not of so much importance as their quality. For the general education of the agricultural people, young and old, other agencies than the four years' college course are to be employed, which will require for their management a large share of the graduates of the agricultural colleges.

Owing to the complicated organization of many of the institutions having courses in agriculture and the fact that the students in agricultural courses in many subjects are in classes with students in other courses, and that much of the equipment is used in common by the students in all the courses, it is impracticable to show by statistics, with exactness, the means and facilities for strictly agricultural education. The general statistics of the land-grant institutions may, however, serve to show with how great an enterprise, devoted chiefly to higher education along scientific and industrial lines, agriculture has been joined in permanent alliance, and to indicate in some measure how extensive are the educational facilities at the command of the youth of the country who have sufficient intelligence, courage, and perseverance to follow out long and thorough courses of study in agriculture.

The aggregate value of the permanent funds and equipment of the land-grant colleges and universities in 1898 is estimated to be as follows: Land-grant fund of 1862, \$10,170,549.99; other land-grant funds, \$1,204,234.44; other permanent funds, \$11,816,258.16; land grant of 1862 still unsold, \$3,838,219.48; farms and grounds owned by the institutions, \$6,046,500.16; buildings, \$15,185,476.95; apparatus, \$1,916,227.85; machinery, \$1,383,137.14; libraries, \$1,634,190.25; miscellaneous equipment, \$1,765,243.19—total, \$53,632,852.25. The income of these institutions in 1898, exclusive of funds from the United States for agricultural experiment stations (\$720,000), was as follows: Interest on land grant of 1862, \$645,546.28; interest on other funds, \$578,067.38; United States appropriation under act of 1890, \$1,108,610.38; State appropriation (annual or regular), \$1,827,924.51; State appropriation (occasional), \$533,794.98; tuition fees, \$480,847.32; incidental fees, \$146,458.72; miscellaneous, \$679,130.93—total, \$6,008,379.20. The value of the additions to the permanent endowment and equipment of these institutions in 1898 is estimated as follows: Permanent endowment, \$1,424,277.64; buildings, \$851,481.75; library, \$105,661.11; apparatus, \$132,111.90; machinery, \$123,477.63; miscellaneous, \$167,336.53—total, \$2,796,350.97. The number of persons in the faculties of the colleges of agriculture and mechanic arts were as follows: For preparatory classes, 254; for collegiate and special classes, 1,564—total, 1,722. In the other departments the faculties aggregated 889, making a grand total of 2,611 persons in the faculties of the land-grant institutions. The students in 1898 were as follows: (1) By classes: Preparatory, 6,593; freshmen, 6,016; sophomores, 4,202; juniors, 3,216; seniors, 2,506; special, 4,526; post graduate, 878—total, 31,658. (2) By courses: Agriculture, 4,181; mechanical engineering, 2,797; civil engineering, 1,504; electrical engineering, 1,698; mining engineering, 554; architecture, 411; household economy, 1,298; veterinary science, 449; military tactics, 8,952. The graduates in 1898 were 2,328, and since the organization of these institutions 34,168. The average age of graduates in 1898 was 22.1 years. The total number of volumes in the libraries was 1,221,226.

SHORT AND SPECIAL COURSES IN AGRICULTURE.

In many of the colleges of agriculture provision has been made for more elementary and practical education in agriculture by establishing short courses. These may continue through two college years or be limited to a few weeks, chiefly in the winter months. Recently, successful short courses have been given at a few colleges in the summer, when the regular college courses were suspended. The short courses may either cover agriculture in general or be confined to some special line, as dairying. Now that the short courses are quite clearly differentiated from the regular college courses in agriculture the objections formerly made to tnem are no longer strongly urged, and in popularity and success they seem to have entered on a prosperous career. The short courses offered by the University of Wisconsin may serve to illustrate the nature of this feature of the American system for agricultural education. "The short course in agriculture," it is stated, "is designed to meet the wants of young farmers who desire practical, helpful instruction in agriculture before taking up their chosen vocation. This course covers two terms of twelve weeks each, beginning the first of January each year." It includes lectures on feeds and feeding, breeds of live stock, agricultural chemistry, agricultural physics and meteorology, plant life, veterinary science, dairying, farm bookkeeping, horticulture, agricultural economics, and bacteriology. Laboratory practice is given in dairying, physics, plant life, stock judging, and horticulture, and practical work in carpentry and blacksmithing. The dairy course occupies one term, and includes theoretical and practical instruction in the science and practice of dairying and dairy farming. It is definitely planned to meet the needs of persons intending "to operate creameries and cheese factories," and has been very successful in training men competent for work of this kind. The students engage in milk testing, operate separators and butter extractors, and attend to the ripening of the cream, churning and packing butter, and all the operations of a creamery and cheese factory.

This dairy school has already sent out 800 trained butter and cheese makers and has also taught nearly 2,000 young men butter making on the farm, as distinct from the creamery. The short course in agriculture at this institution was reported in 1899 to have had 190 students in attendance, and its practical outcome is thus stated by the dean: "We have found places on farms this year for more than fifty young men, who will secure from $2 to $10 more per month because of their training with us."

Another interesting special school is that for training sugar experts, which has been in successful operation for a number of years at Audubon Park, New Orleans, in connection with the State university, and has received financial assistance from the Sugar Planters' Association.

UNIVERSITY EXTENSION IN AGRICULTURE.

The term "university extension" has been used in recent years to denominate in a general way the efforts of our colleges to promote the diffusion of knowledge outside of their own halls. Though not always spoken of under this head, no university extension movement in this country has actually been so widespread as that on behalf of agriculture. Broadly speaking, this would properly include the dissemination of agricultural information through the publications of the experiment stations and this Department. The stations annually issue over 400 publications, which are distributed to mailing lists aggregating half a million addresses, and this Department supplements these with some 600 others, of which about 7,000,000 copies are distributed. But confining ourselves to what would more usually be considered university extension work, we find the colleges of agriculture largely engaged in conducting farmers' institutes and home-reading courses and helping to introduce nature study into the common schools.

IMPORTANCE OF FARMERS' INSTITUTES AS FACTORS IN EDUCATION.

The farmers' institutes are sometimes under the direct management of the agricultural colleges and sometimes are controlled by independent State officers, but in either case the colleges do much of the actual teaching in them and in various ways contribute largely to their success. These institutes are regularly held in over forty States. It is estimated that about 2,000 institutes were held in the United States last year, which were attended by half a million farmers. The importance of the institutes as factors in the general education of farmers in some of the States where they have been most successful may be indicated by the following brief statistics:

In Wisconsin there are now annually held 120 institutes, with an average attendance of over 50,000 persons. Sixty thousand copies of their annual institute bulletin, in which the best addresses are grouped together, making a book of over 300 pages, are annually distributed. A copy of this book is put into every school library in the State. For this work the State appropriates $12,000 annually.

In Massachusetts 125 institutes are held, with an attendance of about 11,000 farmers.

In West Virginia over 60 institutes are held, with a total attendance of 14,000.

In Minnesota 50 farmers' institutes are held of two or three days each, with an attendance of from 300 to 1,000, and 25,000 copies of their annual report are distributed.

In Indiana an attendance is reported of over 25,000, with an average of 272 persons in about 100 institutes.

In Kansas 135 institutes are held, with a total attendance of 20,000.

In Michigan institutes are held in nearly every county, and the total attendance is reported to reach 120,000.

In Nebraska 60 institutes are held, with a total attendance of over 26,000.

In Pennsylvania some 300 institutes are held, with a total attendance of over 50,000.

In Ohio 250 institutes in 88 counties are held, with an aggregate attendance of about 90,000.

In New York over 300 institutes are held in a single year.

In California about 80 institutes are annually held, with a total attendance of 16,000.

HOME-READING COURSES IN AGRICULTURE.

The agricultural colleges in a number of States, notably in Pennsylvania and New York, are carrying on courses of home readings in agricultural subjects. These at present are developing into what may very properly be called correspondence courses. Not only are lists of books furnished by the college, but series of lessons with questions are sent out, and much correspondence is had with the persons following the courses. College officers also visit classes or clubs of farmers who are pursuing these courses to give them advice and instruction along the lines in which they are reading. Thousands of farmers are already enrolled in these courses, and only lack of funds prevents their rapid extension.

SECONDARY COURSES IN AGRICULTURE.

Thus far comparatively little has been done in the United States toward the establishment of schools of agriculture of secondary or high-school grade. As previously stated, a successful school of this grade is maintained at the University of Minnesota, and a similar one has been begun at the University of Nebraska. The agricultural courses maintained in a number of the institutions for colored students in the South are of this grade. In Alabama provision has also been made for secondary schools of agriculture for white students in the nine Congressional districts. There are a few private schools in which agricultural subjects are taught. There is some agitation in favor of the introduction of agriculture in the public high schools, but no definite movement in this direction has as yet been attempted. Meanwhile, however, books of reference and text-books on agricultural subjects suited to this grade of schools are being published in increasing number, and the way is thus being prepared for more rapid development of secondary courses of instruction in the schools in the near future.

AGRICULTURE IN THE COMMON SCHOOLS.

While there has been much agitation at different times during the present century in favor of introducing agriculture into the common schools, thus far no widespread efforts to do so have been made. Under present conditions, it appears to most persons who have made a careful study of the subject that very little can successfully be done in this direction until much preliminary work has been bestowed on the formulation of courses in nature study suited to the needs of the rural schools, on the training of teachers in this line, and on the general introduction of nature teaching in the schools. The success which is attending the movement on behalf of nature study in New York, Indiana, Pennsylvania, and elsewhere is so pronounced that there is good reason to hope that it will ere long secure the general recognition of the value of nature study for young children and its widespread introduction into the common schools. Important features of this movement are the strong indorsement which it is receiving from school officers and teachers, and the fact that nature study has already become quite generally a part of the curriculum in the graded schools of the cities. As this movement in the interest of the rural schools is being led by the agricultural colleges, agriculture seems likely to have its claim fully recognized in the formulation of nature-study courses. Already many of the lessons used in such courses are on subjects directly related to agriculture. Wisely planned and effectively taught, courses on natural objects and phenomena in the common schools will not only train the powers of observation of the children, but will interest them in the subjects included in the theory and practice of agriculture, and thus pave the way for the successful introduction of this complex subject in courses of higher grade.

PRESENT CONDITIONS AND PROSPECTS FOR THE FUTURE.

In general, the century now closing has witnessed an intellectual awakening of the farmers of this country, the volume and depth of which have been increasing with greatly accelerated speed in the past few years. We now have a considerable body of well-trained investigators, teachers, and other promoters of agricultural progress who are working earnestly and with greater success each year to raise the general intelligence of farmers and give them accurate and definite information for the improvement of their art; we have the widespread dissemination of knowledge on agricultural subjects through the press and through public agencies liberally endowed by the States and the nation; we have strong local, State, and national organizations which are laboring diligently for the promotion of the general and technical education of the farmers. Strong institutions for original research and higher education in agriculture have already been built up, and hopeful beginnings have been made in the formulation and introduction of more elementary courses of instruction in agriculture in schools of various grades and among the farmers generally. We shall therefore enter the twentieth century with a reasonable expectation that the education of our farmers in agricultural lines will go on increasing in efficiency and extent, and ere long become general and satisfactory.

PROGRESS IN THE TREATMENT OF PLANT DISEASES IN THE UNITED STATES.

By B. T. Galloway,
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INTRODUCTION.

In looking back over the work of the past century in the treatment of plant diseases, two facts immediately enlist attention: (1) That the last fifteen years have witnessed by far the greatest advances made, and (2) that in every step taken there has been shown the characteristic American spirit of striving to get direct practical results as quickly as possible. For the first three-quarters of the century there was practically no systematic attempt to obtain light on the diseases of crops. Of course, diseases have been recognized as long as plants have been grown, but in all these earlier years it was the custom to regard them more in the nature of obstacles, against which it was practically useless to contend, than as subjects for study and thought.

PRESENT CLASSIFICATION OF PLANT DISEASES.

A few words at this point in regard to present methods of classifying plant diseases will perhaps make clearer the discussion to follow. Briefly stated, diseases may be produced in three ways: (1) By living organisms acting as parasites; (2) by unfavorable environment in which the plant grows; and, (3) by combinations involving both organisms and environment. No line can be drawn between these groups, for their relations and interrelations are so intimate that sharp separation at any point is out of the question. The living organisms, such as fungi, bacteria, etc., produce diseases by attacking the higher plants and destroying them in order to build up their own structures. On the other hand, when the surroundings, such as unfavorable soil, too much or too little food, improper cultivation, excess of water, insufficient aeration of the soil, or other similar conditions occur, disease may follow without the action of such organisms as fungi or bacteria.

It might, however, be held that the plant ought not to be subject to disease produced by organisms, for if it were surrounded by conditions exactly suited to its growth and was at all times able to adapt itself to these conditions, growth would in a measure be perfect, consequently no disease could be produced by outside agencies. But the plant is always in a state of unstable equilibrium, and it is this fact that makes it subject to the attacks of organisms and likely to be injured when any marked change of environment occurs. While this appears to be an element of weakness, it nevertheless affords vast opportunities, and is really the keynote to successful plant culture, as the writer will endeavor to show farther on.

EARLY THEORIES ON PLANT DISEASES.

It is not surprising that the man who grows plants looks to the weather as the source of all that is good or bad. In his own way he learns by experience that the weather has an important relation to the success or failure of his work, and he soon begins to connect certain weather conditions with what he sees going on about him. In all the early literature, therefore, references are found to the effects of "unfavorable weather," "meteorological disturbances," etc.

Other facts gained by long experience were also brought to bear on peculiar phenomena connected with plant diseases and their treatment. Thus, it was known at the beginning of the century and earlier that the injury from wheat rust was influenced by the presence of the common barberry plant. So strong was this conviction that laws were passed prohibiting the growing of barberry for ornament or for hedges. The opinion prevailed that the barberry caused rust, but it was not until many years later that its connection with rust was shown scientifically by the investigations of De Bary in Germany. It was also believed by many of the older agriculturists that smut was the direct result of a rupture of the cells of the plant itself, and that the rust of wheat was often produced by similar causes. Not only was this the general belief among many agriculturists, but it was credited by a number of workers abroad who made special studies of the subject.

About the year 1845, largely through the efforts of one or two investigators abroad, light began to dawn upon the nature of a number of the common diseases of plants, and these efforts were destined to have a marked influence on all future knowledge bearing on this subject. Although there was as yet no systematic attempt in this country to make special investigations, the work done abroad was gradually made known here, and through the agricultural press and other sources, became more or less familiar to farmers and others interested.

The great prevalence of the potato-rot fungus about this time (1845) gave a decided impetus to work on plant diseases. The rot swept over the earth, and many attempts were made to discover its cause and to provide a remedy. The relation of the parasite to the disease was worked out in Germany, and this knowledge soon became known to the farmers of this country. The same was true of wheat rust, corn smut, etc., so that even in these early days there was some knowledge of treating diseases by the direct use of remedies or preventives. This is particularly true of the smuts, which were among the first diseases to be controlled by the use of substances designed to destroy the reproductive bodies of the fungi themselves. Aside from this, the principal efforts in the way of treatment were in the direction of giving the plants the best surroundings possible and treating wounds by the use of simple paints, wax, etc.

Experience had taught that blight of the pear and apple must be cut out, although believed to be due entirely to "atmospheric influences." This emphasizes the important fact that has already been referred to, that is, that although the growers of plants did not, as a rule, concern themselves much with the causes of diseases, their experience had taught them certain methods of treatment which in some cases are even to-day accepted as the best that can be followed.

THE BEGINNING OF MODERN RESEARCH.

From 1845 until 1861 there was considerable advance in knowledge concerning plant diseases, particularly as regards their causes, or in other words, the relation to them of certain parasitic organisms. This knowledge came about largely through the investigations of a few men in Europe. From 1861 to 1873 the accounts of investigators abroad were published from time to time in our horticultural and agricultural reports and in agricultural and other journals. There was an increasing interest in the subject, however, and it is not surprising that in 1873 and 1874 there was a marked tendency to advance in knowledge along these lines.

Prof. T. J. Burrill, of the University of Illinois, was one of the pioneers in this field. Early in 1874 he commenced publishing articles on the parasitism of fungi and the relation of various organisms of this kind to such diseases as leaf blights, rusts, and other maladies. The following year Dr. W. G. Farlow, of Harvard University, began a series of papers which were epoch making in their nature. These papers dealt with a number of important diseases of plants and treated them in a masterly way. Although up to this time knowledge as to combating such diseases was limited, the information obtained in regard to the life histories of the organisms and the manner in which they attack the host plants and cause their death was of great value in suggesting lines of action looking toward prevention. Farlow's papers were followed by similar ones by Halsted, Bessey, Trelease, Earle, Arthur, and others.

Early in the eighties the interest in the subject became marked, as may be seen by the increased number of papers and the fact that some of the universities and colleges were devoting time to lectures and studies relating to the work. The State agricultural experiment station at Geneva, N. Y., inaugurated some important work under the direction of Dr. J. C. Arthur, who was made botanist of the station in 1884, and whose work was almost entirely on the diseases of plants. This was really the first systematic attempt on the part of any station or organized body in the United States to undertake a thorough study of the subject. Dr. Arthur published four reports, which dealt with a great number of important diseases. He paid particular attention to pear blight, which was recognized as one of the most destructive diseases of fruit in the United States, and had already been shown by Dr. Burrill to be due to bacteria. Dr. Arthur's work tended to establish more thoroughly the parasitic nature of a number of fungi. The keynote to the practical work of treatment had not yet been struck, but was to come later as a natural result of the studies made at this time.

THE EPOCH-MAKING PERIOD FROM 1885 TO 1895.

A careful study of events, such as are to be described here, shows that in nearly every case where a line of work stands out preeminently as having a marked influence on the welfare of a country, two things have conduced to this end: (1) Through writings, lectures, and other channels the public has been educated so as to understand its need in this direction, and (2) after the recognition of this need there has been the proper direction of the forces necessary to satisfy it.

Prior to 1885 much had been done toward educating the farmers and fruit growers to the necessity of protecting their crops. There was a well-grounded belief that many of the common and destructive diseases owed their existence to causes which could be discovered, and which if once known might be controlled. The time, therefore, was ripe for starting the work on a more extensive scale than had ever been done before. The demand at this time was largely for information as to the best methods of treatment from a practical standpoint. It was not so much a question of knowing what the diseases were as it was how to best get rid of them. Recognizing these questions and their importance, the Department of Agriculture inaugurated some work which was destined to have far-reaching effects. F. Lamson-Scribner, who was assistant botanist at the time, was active in bringing about a proper recognition of the importance of the work. He undertook the publication of papers, which appeared first in the report of the Botanist of the Department of Agriculture. Soon such an interest was awakened that the Commissioner of Agriculture, Hon. Norman J. Colman, took steps to have the work put on a sound basis. Small appropriations were obtained, and the Section of Mycology was established as a distinct branch in the Department. Fortunately, a great impetus was given to the work at this time by the efforts being made in France to find remedies for the downy mildew of the grape. When black rot, another American disease, appeared in the French vineyards, there was widespread alarm, and consequently renewed efforts to find means of checking it.

It is well to call attention to the marked difference in the conditions existing in France and in this country with respect to such matters. Our country is so great, and the possibilities of diversified culture so numerous, that many farmers and fruit growers do not feel the necessity of putting forth any marked effort in treating the diseases. In France, however, the life of the community itself depends in many cases on the success or failure of a particular crop in that community, and so it was that the greatest pressure was brought to bear on the French Government to make a determined effort to check the ravages of downy mildew.

Through a fortunate accident—the sprinkling of vines bordering a roadside with bluestone and lime in order to prevent the pilfering of the fruit—there was discovered about 1885 a fungicide which was to have a marked influence not only on the welfare of France, but also on the interests of America as well. This fungicide thus accidentally discovered is the so-called Bordeaux mixture, which is made by combining copper sulphate, or bluestone, with lime. It has long been known that copper in various forms is able to destroy fungus spores, but it was not until the discovery of the Bordeaux mixture that a great impetus was given to the study of its effects on many plants. No one could have imagined the consequences which were to come from the combined use of two such simple things. Not only was the fruit saved from the thieves, but it was protected against mildew as well.

Soon after the success in France in the treatment of grape mildew with Bordeaux mixture, its usefulness was noted in this country by the Department of Agriculture and also by others. It was difficult, however, to convince fruit growers of the importance of making thorough trials of this and other preparations. This was one of the greatest obstacles that the Department met with in the early stages of the work. However, circulars were sent out describing the preparation of the fungicide and suggesting diseases that might be effectively treated with it. The success of the work was marked. Immediately there sprang up probably one of the most remarkable series of investigations and experiments ever witnessed in this or in any other country. Fungicides of many kinds were proposed and tested on a large scale, and extensive lines of investigation were inaugurated not only by the Department of Agriculture, but also by private individuals in various parts of the country.

In 1887 Professor Lamson-Scribner severed his connection with the Department of Agriculture, accepting an appointment to the chair of botany in the University of Tennessee, and the Department's work in this line was put in charge of the writer. The investigations were pushed forward as vigorously as possible; new lines of investigation were inaugurated, and a special effort was made to bring about practical results. Black rot of the grape was successfully treated in 1887, and the same year decisive results were obtained in controlling several potato diseases.

A great impetus was also given to the work in 1887 by the establishment of the agricultural experiment stations. By means of these stations it was made possible for many of the States to inaugurate work not only in the study of plant diseases and their treatment, but also in many other lines of investigation as well. Several of the stations immediately commenced investigations, and as a result for the next eight years the educational work done throughout the country had the most remarkable effect in putting farmers, fruit growers, and others in possession of knowledge most valuable to them. During the period under consideration a revolution was wrought in our horticultural methods, and, as a result, it is now as rare to find people who are not thoroughly convinced of the importance of spraying as it is to find those who are satisfied that the cultivation of the soil is not necessary.

This vast amount of work on the fungicides carried with it the necessity of providing suitable apparatus for the application of the various preparations, there being a great need for such apparatus when the work was started. Just prior to the beginning of the important line of work in 1885 attention had been called to the value of the cyclone nozzle, an apparatus invented by Dr. W. S. Barnard while connected with the United States Entomological Commission. Although this nozzle was designed for the application of insecticides, it was found that with some minor changes it would be equally as valuable for use in connection with fungicides. There was also an urgent need in 1887 for suitable power pumps for the application of the various preparations. Some advances had been made with such apparatus in France, particularly in the knapsack forms, but such of these as were in actual use were more or less cumbersome, and none could be obtained in this country. Early in 1887 the first American knapsack pump was put on the market, largely through the efforts of Col. A. W. Pearson, of Vineland, N. J., who was one of the pioneers in the work of treatment. The machine was somewhat complicated, however, and did not attract the attention that it really deserved. In 1888 the writer devised a new form of knapsack spray pump, which was soon put on the market, and this became the pattern from which many designs have been made. In a few years such was the demand for apparatus of this kind that numbers of machines were manufactured. The knapsack forms of sprayers have had a marked influence in the success of the work described. Through them it was made possible to apply the remedies in the most thorough manner, a feature which is of the greatest importance in such work. As a direct result of this work many other forms of sprayers were designed; in fact, in this feature of the investigation the United States can well claim to have constantly led the way.

SOME RESULTS OF THE WORK.

The ten years' work just described was unique in its way. There was a united effort to concentrate on as many practical problems as possible, with a view of solving these first and attending to the more difficult ones later. Immediate results were demanded, and by obtaining them confidence was engendered; and thus the foundation for future efforts was laid. Within the limits of such a paper as this, it is not possible to review all the direct practical results of the work in question, but a few examples will suffice.

GRAPE GROWING.

One of the most striking examples of results obtained is furnished by the grape. Grape growing in this country has had a curious history. At the beginning of the century numerous attempts had been made to introduce and grow the foreign or European varieties. It was recognized that in this vast country abundant opportunities were offered for the production of grapes and the manufacture of wine. Our native varieties were not considered of value, and for this reason all the early efforts were put forth in importing and testing the foreign, or Vinifera, vines. All the attempts in this direction, however, proved disastrous, mainly on account of several diseases, which, from all that can be gathered, were the same as those known to-day as downy mildew and black rot.

After many discouraging attempts to successfully cultivate these European vines, the work was in a measure abandoned and attention was turned toward our native varieties, many forms of which were found growing in the woods. Some of these vines proved to be resistant to the diseases, no doubt because through a long struggle for existence there had been a survival of the fittest, and these were by nature endowed with the ability to resist the various maladies which had been so destructive to European vines. The diseases being American, the European vines had had no chance to develop anything like natural resistance before being attacked.

The discovery of the value of some of our native kinds gave the grape industry a new impetus, but as soon as vineyards began to increase and cultivation brought about changes in the vines themselves it was found that the latter were becoming more and more subject to the attacks of their old enemies. Consequently there are recorded many disastrous failures in grape culture between 1850 and 1860, when mildew and black rot were veritable scourges. In a number of places where grape culture had been very profitable the vineyards had to be abandoned. New localities, in which the grape had not been tried, were now planted to vineyards, and for a time these produced remunerative yields, but it was only a question of time when the diseases reached these places and it became necessary to abandon them and again seek more favored localities.

By 1885 grape growing had been tried in most of the important sections of the country, and as the diseases continued to spread it was realized that something would have to be done or else the industry would have to be abandoned. At this time the work of the Department of Agriculture commenced, but so many efforts had already been put forth to control the diseases and there had been so many failures that it required a great deal of encouragement to induce growers to even make thorough trials of the treatments proposed. By carrying on experimental work in typical regions, however, and by demonstrating by actual trials that the treatments were effective (fig. 1), the value of the work was fairly established, and consequently fungicidal treatments were rapidly adopted. The money value of this

FIG. 1.—Grapes from vineyard affected with black rot: Sprayed and unsprayed.

work to the grape grower can not be estimated. It has given viticulture a new lease of life and has furnished profitable employment in many regions which otherwise would have been abandoned, so far as this crop is concerned.

NURSERY-STOCK DISEASES.

Prior to 1887 no attempt had been made to control the many serious diseases which affect nursery stock in this country. The nursery interests had assumed immense proportions and the value of the output was worth millions of dollars. Nursery stock, such as apples, pears, plums, cherries, etc., had long been subject to a number of serious diseases, which mainly affected the foliage. Often as a result of these injuries it was found impossible to properly bud the stock, and a large part of it was therefore rendered worthless.

In 1888 the Department of Agriculture inaugurated the first experiment with a view of finding some means of holding these diseases in check. After several years' work it was clearly shown that some of the most destructive maladies could be controlled (fig. 2). Spraying nursery stock, therefore, has come to be a general practice, and has been the means of saving thousands of dollars to the growers every year. The Department and the State stations have gone hand in hand in this work, and some of the most striking features of the practical side of the investigations have come about through the efforts

FIG. 2.—Treatment of peach leaf curl: Sprayed and unsprayed trees. (Pierce, Cal.)

of the latter. Potato scab, the smuts of cereals, and many other diseases are now controlled as a result of the good work done by these organizations.

DEVELOPMENT OF EDUCATIONAL FEATURES.

Perhaps there is no more striking instance of the growth of this subject than that witnessed in the development of the educational features connected with it. In 1885 there were only three institutions besides the Department of Agriculture making an organized effort in the way of teaching or in experimental work of this character. Ten years later there were fifty colleges and stations engaged in the work, and no less than one hundred special investigators were devoting their time to it.

THE PRESENT AND THE FUTURE OF PLANT PATHOLOGY.

Since 1896 there has been a marked tendency toward a higher appreciation of a true science of plant pathology. The outlying problems have in a measure been solved and opportunity has been given to survey and take a clearer view of the fundamental questions upon which the future success of the work must depend. We are far enough along to see that a new epoch has begun—one which we believe is to place this country in advance of all others in getting the most from the soil with the least expenditure of time and money. Our farmers and fruit growers are intelligent, quick to perceive, and quick to act. They are now in possession of knowledge which gives them a decided advantage over their competitors in other countries, and therefore it will not be difficult with such men and such conditions as we have to build up a science which will have a marked influence on the welfare of the country.

What then are the lines along which this science is to be built? First, we must recognize more plainly the possibilities within the plant—its plasticity and its ability to change; second, we must learn to look more carefully outside of the plant, that is, at its environment and the effects this may produce; and, third, we must discover the principles whereby the grower of plants shall be able to bring about such perfect harmony between the plant and its environment that an approximately ideal organism will result. This means that our aim should always be toward making two blades of grass grow where only one grew before.

The foundation of this work is physiology, involving a study of the phenomena of life itself. Here we learn the possibilities of future development, and here hinge the vital questions relating to nutrition and heredity. The pathology of the future, therefore, will not stop at the mere correction of conditions involving the loss of a crop or part of a crop. It will put within the power of the intelligent grower knowledge that will enable him to forestall injuries by furnishing conditions best suited to the development of the plant. We must bring to our aid many lines of work. Plant breeding will enable us to attain ideal forms. Selection will make it possible to fix these forms within certain limits. Nutrition goes hand in hand with breeding and selection. Chemistry and physics play important parts, and in the study of pathological phenomena themselves other branches of science will be brought to bear. Thus, as we have pointed out elsewhere, the highest aim of the investigator in this field will be not to deal with effects only, but to study causes, for it is only by such means that the greatest good can be accomplished.

THE RELATION OF CHEMISTRY TO THE PROGRESS OF AGRICULTURE.

By Dr. H. W. Wiley
Chemist.

Introduction.

This paper will be devoted, in so far as possible, to the progress of agriculture in the United States during the nineteenth century. Inasmuch, however, as the factors of a chemical nature influencing agriculture are largely made up of forces emanating from other countries, it will not be possible to separate entirely the discoveries made in foreign countries from those made in the United States.

In order to keep the paper within suitable limits for the Yearbook, no attempt will be made to trace the progress of agriculture in its relation to chemistry from year to year, and the subject will be considered from three principal points of view only, namely:

(1) The relation of chemistry to agriculture at the beginning of the century.

(2) The impetus given to scientific agriculture in its relation to chemistry by the discoveries of Liebig, Gilbert, Boussingault, and other workers, which began to produce effects about the middle of the century.

(3) A résumé of the relations of chemistry to agriculture up to and at the present time, with a brief reference to the principal methods whereby chemical research has been made useful to practical agriculture.

The above is not only a convenient division of the whole subject for the purpose of discussion, but it also portrays the three principal epochs in the relations of chemistry to agriculture for the century.

From a chemical point of view, the knowledge of scientific agriculture, as it existed at the beginning of the century, was practically all that was known until near its middle point, when the work and researches of the distinguished men mentioned and others associated with them were beginning to have practical application. From this point onward to the present time the influence of chemical research on progressive agriculture has been more and more felt through certain lines of investigation, until it has brought the science of agriculture to its present condition.

In a statement of that part of the subject relating to chemistry and agriculture at the beginning of the century it will be sufficient to refer to the standard works which were published at or about that time, and which are still accessible in our libraries. The literature of the middle of the century is so voluminous that only a brief reference to it can be given. In a discussion of the third division of the subject, or a review of the relations of chemistry to agriculture to the present time, etc., the progress of agriculture under the influence of chemical studies and researches will be considered in the briefest possible manner in several typical lines, among which may be mentioned: First, the teaching of agriculture in schools, colleges, and universities; second, the agricultural colleges and experiment stations; third, the agricultural press; and, fourth, the chemical studies conducted under the auspices of the Department of Agriculture, including those collected in the reports of the Patent Office relating to agriculture, which began to issue shortly before the middle of the century.

The attitude of chemical science toward agriculture at the beginning of the century may be presented under three divisions:

(*a*) The knowledge which was possessed concerning the nature of the soil and its relation to plant growth.

(*b*) The knowledge possessed concerning the nature of manures and the manner in which they increase the yield of crops.

(*c*) The prevalent ideas concerning the composition of agricultural crops in relation to their demands upon the soil and upon fertilizers.

Status of Agricultural Chemistry at the Beginning of the Century.

Under this head will be given, first, a summary of the state of knowledge at or about the beginning of the century in regard to the above several points, and second, some brief observations of a general nature on the soundness or unsoundness of the views then held.

Fortunately for the purpose of this part of the paper, the relations of chemistry to agriculture at the beginning of the century have been accurately and faithfully portrayed in works appearing near that period and still accessible. Among these may be mentioned:

A work of great scientific importance entitled "The Natural and Chemical Elements of Agriculture," translated from the Latin of Count Gustavus Adolphus Gyllenborg by John Mills, published in London in 1770.

"The Spectacle of Nature," translated from the French by Mr. Humphreys, the first edition of which was published about the beginning of the century, and the second edition, to which the writer has had access, about 1807.

The most important work, however, from a scientific point of view, and that which gives the most accurate statements pertaining to the relation of chemistry to agriculture, is a compilation of the lectures of Sir Humphry Davy. These lectures, delivered before the Royal Agricultural Society of England, were first published in England in 1813 and republished in this country in 1815 by John Conrad & Co., of Philadelphia, Pa.; Fielding Lucas, jr., of Baltimore, Md.; Robert Gray, of Alexandria, Va., and William F. Gray, of Fredericksburg, Va.

Another work of a more popular nature, and yet containing a résumé of the knowledge of that time concerning the relations of chemistry to agriculture, is entitled "The Rural Socrates; or, An account of a celebrated philosophical farmer, lately living in Switzerland, known by the name of Kliyogg." It was translated from the German by Benjamin Vaughan, a writer distinguished in many fields of work and a personal friend of Joseph Priestley. This work was published in Hallowell, Me., by Peter Edes in 1800.

Chemistry as a science has undergone such a wonderful transformation during the century as to make any just comparison of its relation to any particular industry at the present time with that it held a hundred years ago somewhat difficult. We regard with a feeling akin to compassion the ideas entertained one hundred years ago in reference to chemistry, especially in its relations to agriculture; but the pride we may feel in our present knowledge of this science should not be allowed to carry us too far, since at the end of the next century the writer who shall undertake a review of this subject may look with equal compassion on the views we now entertain.

The efforts which were made by Lavoisier and his school to place the science of chemistry upon a sure foundation some twenty-five years before the beginning of the century, although making great progress, had not yet entirely dominated the world of chemical theory. The crude notions of the earlier chemists concerning phlogiston, phlegms, essential oils, exudations, evaporation, and other processes still held sway, and agricultural chemistry was probably the last of the different branches of chemical science to be liberated from the thraldom of these erroneous theories. In spite of this fact, however, the observations which scientific men had made of the chemical aspects which agricultural science possessed are not without value nor are they wholly false.

KNOWLEDGE OF THE COMPOSITION AND FUNCTIONS OF SOILS.

By far the most accurate account of the composition of the soil, as it was understood at the beginning of the century, is furnished by Sir Humphry Davy.[1] According to Davy the substances which constitute the soil "are certain compounds of the earths, silica, lime, alumina, magnesia, and of the oxides of iron and magnesium; animal and vegetable matters in a decomposing state, and saline, acid, or alkaline combinations." Minute descriptions are given of the various elements composing the soil, and for the most part these descriptions represent the state of our knowledge even at the present time. Silica is described as a compound of oxygen and silicum. Lime is

[1]Agricultural Chemistry, pp. 154 *et seq.*

stated to exist in soils usually united with carbonic acid, and sometimes with phosphoric and sulphuric acids. Lime itself is said to consist of 40 parts by weight of calcium and 15 of oxygen, which is very nearly the composition assigned to the substance CaO at the present time. Alumina, with less accuracy, is described as being composed of 33 parts by weight of aluminum and 15 of oxygen. Magnesia is described as existing in combination with carbonic acid. Two oxids of iron are mentioned, the brown and the black, and their chemical composition as understood at that time is given. The oxid of manganese, or manganesum, as Davy calls it, is stated to be distinguished from the other substances found in the soil by its property of reducing muriatic acid and converting it into chlorin. Vegetable and animal matters are to be known by their sensible qualities and by their property of being decomposed by heat. The saline compounds of soils are described as common salt, sulphate of magnesia, sometimes sulphates of iron, nitrates of lime and of magnesia, sulphate of potassa, and carbonates of potassa and soda. These compounds Sir Humphry regards as of so little importance that he says it is not necessary to describe their characteristics minutely.

The methods of soil analysis, many of which are still in use at the present time, are fully described. Upon the whole, most of them, however, are crude and unsatisfactory, and could not possibly have led to correct ideas of the composition of the soil. Davy further adds: "In the first trials that are made by persons unacquainted with chemistry, they must not expect much precision of result. Many difficulties will be met with; but in overcoming them the most useful kind of practical knowledge will be obtained, and nothing is so instructive in experimental science as the detection of mistakes. The correct analyst ought to be well grounded in general chemical information; but perhaps there is no better mode of gaining it than that of attempting original investigations."

Davy fully recognized that the soil is the source of nourishment for plants, as he says in another place: "Plants being composed of no locomotive powers, can grow only in places where they are supplied with food; and the soil is necessary to their existence, both as affording them nourishment and enabling them to fix themselves in such a manner as to obey those mechanical laws by which their radicles are kept below the surface and their leaves exposed to the free atmosphere. As the systems of roots, branches, and leaves are very different in different vegetables, so they flourish most in different soils. The plants which have bulbous roots require a looser and a lighter soil than such as have fibrous roots, and the plants possessing only short fibrous radicles demand a firmer soil than such as have taproots or extensive lateral roots."

Of vegetable and animal matters Davy says: "Vegetable or animal matters when finely divided not only give coherence, but likewise softness and penetrability; but neither they nor any other part of the soil must be in too great proportion, and a soil is unproductive if it consist entirely of impalpable matters." He says of mineral constituents: "Pure alumina or pure silica, pure carbonate of lime, or carbonate of magnesia are incapable of supporting healthy vegetation. No soil is fertile that contains as much as 19 parts out of 20 of any of the constituents that have been mentioned."

Again, he says: "In all cases the ashes of plants contain some of the earths of the soil in which they grow; but these earths, as may be seen by the table of ashes afforded by different plants given in the last lecture, never equal more than one-fiftieth of the weight of the plant consumed. If they be considered as necessary to the vegetable, it is as giving hardness and firmness to its organization. Thus, it may be mentioned that wheat, oats, and many of the hollow grasses have an epidermis principally of the siliceous earths, the use of which seems to be to strengthen them and defend them from the attacks of insects and parasitical plants."

The physical quality of earths in their relation to water are fully exploited by Davy. He says: "The power of soils to absorb water from the air is much connected with fertility. When this power is great, the plant is supplied with water in dry seasons, and the effect of evaporation in the day is counteracted by the absorption of aqueous vapor from the atmosphere, by the interior parts of the soil during the day, and by both the exterior and the interior during the night."

In regard to the food of plants, Sir Humphry states: "Water and the decomposing animal and vegetable matter existing in the soil constitute the true nourishment of plants, and as the earthy parts of the soil are useful in retaining water, so as to supply it in the proper proportions to the roots of the vegetables, so they are likewise efficacious in producing the proper distribution of the animal or vegetable matter; when equally mixed with it, they prevent it from decomposing too rapidly, and by their means the soluble parts are supplied in proper proportion."

In speaking of the derivation of soils from rocks, he says: "The best natural soils are those of which the materials have been derived from different strata, which have been minutely divided by air and water and are intimately blended together; and in improving soils artificially the farmer can not do better than imitate the processes of nature. The materials for the purpose are seldom far distant; coarse sand is often found immediately on chalk, and beds of sand and gravel are common below clay. The labor of improving the texture or constitution of the soil is repaid by a great permanent advantage; less manure is required, and its fertility insured. The capital laid out in this way secures forever the productiveness and consequently the value of the land."

Commissioner Newton, in his first Annual Report, paid a fitting tribute to the services of Sir Humphry Davy in establishing agricultural chemistry as a separate department of science. He says, speaking of the board of agriculture established by Pitt in 1793:

More than all, the board was instrumental in employing Sir Humphry Davy to make those experiments which are not only an honor to intellect, but which established agricultural chemistry as a department of science, and are of inestimable value. He delivered his lectures on this subject in 1802. The fundamental principle which he developed and demonstrated was this—that the productions of the soil derive their component elements, which for the most part are hydrogen, oxygen, and nitrogen, either from the atmosphere by which they are surrounded or from the soil in which they grow. He showed that the process of vegetation depends upon the perpetual assimilation of various substances to the organs of the plants in consequence of the exertion of their living powers and their chemical affinities, stimulated chiefly by moisture, light, and heat. The discoveries in chemical science before Davy's time had undoubtedly prepared the way for his triumph, but he is none the less entitled to praise. He first recognized a plant as a living thing, the laws of whose existence were to be studied in order to develop a perfect growth. He showed, by analysis of soils and plants, what properties and conditions would best furnish the elements needed in cultivation.

KNOWLEDGE OF FERTILIZERS AND MANURES.

The chemical knowledge of the composition and functions of fertilizers at the beginning of the nineteenth century was extremely nebulous. Experience of a wholly empirical nature had shown from the earliest history of agriculture the value of certain refuse products of the stable and the barnyard in increasing the yield of crops; but the component parts of these materials and the manner in which they acted were entirely unknown. It was the custom in many of the older countries for the farmers to increase the litter of the farmyard by gathering leaves and twigs, which were used in bedding the animals. As, for instance, it was said of Kliyogg: "He is attentive also to gather all the dried leaves, moss, and rushes from his ground that can serve for litter. * * * A compost dunghill appears to him an object of so great importance to the improvement of land that of all branches of labor he regrets the want of assistance in this the most. * * * In prosecution of this design, in autumn, during the moon's increase, Kliyogg goes into his wood with a hedge bill to prune the supernumerary branches of fir and pine trees. * * * These he binds into faggots and carries home. * * * At leisure hours, and especially in long winter evenings, he prepares these faggots for the purposes intended. * * * By this method he amasses many proper materials for good manure."[1]

Kliyogg was also careful to preserve the liquid manures which exuded from his stables, and for this purpose he constructed trenches in his cow houses. It is interesting to know that, unwittingly, he had

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[1] The Rural Socrates; or, An Account of a Celebrated Philosophical Farmer, Lately Living in Switzerland, Known by the Name of Kliyogg, p. 8.

discovered the true function of much of this material, which he regarded as a ferment. The record says: "Thus placed, it receives the urine and dung of his cattle, and being always kept half full of water, it forms a thick mixture and serves as a ferment, with which a very great quantity of water may in a very short time be converted into liquid manure. One portion of this ferment being mixed with seven portions of the freshest spring water soon makes the whole become corrupt, especially if the reservoir in which the mixture is made is of wood and placed in a warm situation, or if an artificial heat is substituted in case a natural heat is wanting. By means of this fermentation an excellent manure is produced, which proves the best assistant which can be given to such meadow and arable lands as are naturally dry."[1]

The earlier accounts of scientific agriculture at the beginning of the century recognized the great value of gypsum as a fertilizing material. All the writers refer favorably to its use. The use of gypsum as a fertilizer is said to have been the discovery of the Rev. Mr. Meyer, pastor of Kupferzell, Germany. Mr. Meyer published a detailed account of the manner of using gypsum. According to the method described by him, gypsum should be spread in its natural state after being reduced to powder, and is useful upon meadows containing both the common and cultivated grasses. Mr. Meyer also found gypsum valuable with peas, vetches, lentils, oats, rye, and tobacco. Its most surprising effect, however, was upon clover, and this in soils the most dry and arid. On marshy ground it was found to produce no good effect. It is urged that gypsum should be spread upon the grass or grain before it begins to shoot. Upon meadows, the best time for spreading it is stated to be at the melting of the snow, and upon fields of grain, as soon as they are sown. Benjamin Vaughan, the translator of "The Rural Socrates," says that at the end of the last century and at the beginning of the present gypsum was used largely in the United States, and he refers to the writings of Judge Peters, Robert Morris, Dr. Mitchill, Mr. Bordley, and others on the subject.[2]

The use of marl was also fully understood at the beginning of the century. Since the time of the Roman conquest, and probably before, the marl beds of northern France and southern Belgium have been constantly exploited. Great hollows are found in many of the fields of northern France made by the excavation of marl many centuries ago. Kliyogg calls the marl bed "that mine of farming gold," and says: "I owe to this marl not only abundant harvests, but the character of my children. It is true that they murmured against me at first for employing them in hard labor, even during the winter. * * * But at length the rich harvests with which Providence blessed us

[1] The Rural Socrates; or, An Account of a Celebrated Philosophical Farmer, Lately Living in Switzerland, Known by the Name of Kliyogg, p. 128.

[2] Ibid., pp. 128 and 129.

forced them to confess that I had said nothing which was not both true and useful."[1]

The true function of marl, however, was but little understood, and even its chemical composition was practically unknown by those using it.

In the article on husbandry, in "The Spectacle of Nature," the Prior, in conversation with the Chevalier, says in regard to manure: "This manure, which completes what the dews of heaven had begun, is the most contemptible substance upon the face of the earth, and is chiefly composed of the litter taken from stables and sheepfolds; dove houses, hencoops, and the dwellings of all domesticated animals furnish manures that differ in their degrees of heat, and which being blended together, as well as quenched and corrected by each other, replenish the land with all the fertility it had lost." Among other substances which the Prior mentioned as being used for manures are straw, stubble, shells of pulse, useless leaves, refuse of garden herbage, rotten wood, chimney and oven soot, rags, hair of animals, cuttings of leather, skins of beasts, bark of trees, lees of wine, sediments of oil, malt dust, tanners' bark, dyers' lees, soapsuds, of which last it is said, "which are commonly thrown out of the laundry as useless, though soap is impregnated with oils and salts, which are the principal elements of plants."

The Prior also says: "No kind of manure has more prolific qualities than the soil which is swept from populous cities, and especially those where a great number of kitchens and dyers of wool are continually discharging into the streets a fat and oily sediment, which is very beneficial to corn."[2]

The value of ashes is fully recognized, in the essay on husbandry, by the Prior, who says that they can supply the place of all the rest if a sufficient quantity can be obtained. The ashes of wood are preferred to those of any other substance. He advises the burning of turf for the purpose of securing the ashes. The methods of forming composts with ashes are fully described.

The prevailing idea at that time that oil is one of the most valuable of manures is developed in his description, it being stated that "oil and salts constitute the chief merit of the manure."

The fact that the principal value of the ashes is due to the potash and phosphoric acid which they contain was not even suspected by the earlier scientific agriculturists. The early agriculturists in our country were imbued with the customs of their European homes in regard to the use and value of manure, although upon the virgin lands there seemed to be but little necessity for the application of fertilizing substances. The necessity of fertilizers, however, soon became evident, especially on lands planted continuously to cereals and to tobacco. When the first abundant crops, due to the virgin fertility of the soil, began to

[1] The Rural Socrates, pp. 143 and 144. [2] The Spectacle of Nature, pp. 231 and 232.

diminish, the colonists received a valuable lesson in the use of artificial fertilizers from Squanto, one of the leading Indians of the New England coast. In Governor Bradford's "History of Plimouth Plantation" is given an account of the early agricultural experiences of the Plymouth colonists. In April, 1621, at the close of the first long, dreary winter, "they [as many as were able] began to plant their corne, in which service Squanto [an Indian] stood them in great stead, showing them both ye manner how to set it, and after how to dress and tend it. Also he tould them, axcepte they got fish and set with it [in these old grounds], it would come to nothing; and he showed them yt in ye middle of Aprill, they should have store enough come up ye brooke by which they begane to build and taught them how to take it."

In George Mourt's "Relation; or, Journal of the beginning and proceedings of the English Plantation settled at Plimouth, in New England, by certain English adventurers, both merchants and others," London, 1622, it is said:

We set the last spring some twenty acres of indian corn, and sowed some six acres of barley and pease, and according to the manner of the Indians, we manured our ground with herrings, or rather shads, which we have in great abundance and take with great ease at our doors. Our corn did prove well, and, God be praised, we had a good increase of indian corn, and our barley indifferent good.

Thomas Morton, in his "New England Canaan," London, 1632, wrote of Virginia:

There is a fish (by some called shadds, by some allizes) that at the spring of the yeare passe up the rivers to spawn in the pond, and are taken in such multitudes in every river that hath a pond at the end that the inhabitants doung their ground with them. You may see in one township a hundred acres together set with these fish, every acre taking 1,000 of them, and an acre thus dressed will produce and yield so much corn as three acres without fish; and least any Virginea man would infere hereupon that the ground of New England was barren, because they use more fish in setting their corne, I desire them to be remembered, the cause is plaine in Virginea, they have it not to sett. But this practice is onely for the indian maize (which must be set by hands), not for English grain; and this is therefore a commodity there.

The following amusing quotation is from the records of the town of Ipswich, Mass., May 11, 1644:

It is ordered that all the doggs for the space of three weeks from the publishing hereof shall have one legg tyed up, and if such a dogg shall break loose and be found doing harm the owner of the dogg shall pay damage. If a man refuse to tye up his dogg's leg, and hee bee found scraping up fish in a corn field, the owner thereof shall pay twelve pence damage, beside whatever damage the dogg doth. But if any fish their house lotts and receive damage by doggs, the owners of these house lotts shall bear the damage themselves.

It is thus seen that even on the old ground cultivated by the Indian before the advent of the colonists it was not possible to raise good crops except by the artificial manuring which has been described above. Little was known, however, of the nature of these fertilizing materials and the manner in which they nourished plants. The first real knowledge of fertilizing materials which was in vogue in this country came from the republication of Sir Humphry Davy's "Agricultural Chemistry" and its distribution throughout the colonies. It may be stated that this book produced the first real impression, of a scientific nature, of the relation of chemistry to the progress of agriculture. Many of the lectures given by Sir Humphry Davy were on the subject of manures, in which he treated of the manures of vegetable and animal origin, of the manner in which they became the nourishment of the plant, of fermentation and putrefaction, of mixed manures, of general principles in respect of the use and application of manures of mineral or animal origin, of fossil manures, of lime, of gypsum, of alkaline salts employed as manures, of alkalies, and of common salt. He also gave a lecture on the improvement of land by burning and the chemical principles which underlie this operation. He first announced the general principles that all manures must practically be dissolved before they can enter the organism of the plant. He says: "The pores in the fibers of the roots of plants are so small that it is with difficulty they can be discovered by the microscope. It is not, therefore, probable that solid substances can pass into them from the soil."[1]

Sir Humphry supposed that sugar was a valuable fertilizing material, because when he grew plants in a solution of sugar, jelly, and mucilage he found that they grew vigorously. He recognized the fact that vegetable and animal substances, before they can become useful as plant food, must be changed in some way, since he says, "They can only nourish the plant by affording solid matters capable of being dissolved by water or gaseous substances capable of being absorbed by the fluids in the leaves of vegetables. * * * The great object in the application of manure should be to make it afford as much soluble matter as possible to the roots of the plants, and that in a slow and gradual manner, so that it may be entirely consumed in forming the sap or organized parts of the plant. * * * Vegetable manures in general contain a great excess of fibrous and insoluble matter, which must undergo chemical changes before they can become the food of plants."[2]

Chief among these changes he regarded fermentation, thus recognizing at that early date the great principle of change which organic matters must undergo before they become useful as plant foods. Sir Humphry, however, was familiar only with the variety of fermentation which produced carbonic acid and alcohol, and of course had no knowledge of the really essential fermentation, from a fertilizing point of view, which such substances undergo. He, however, realized that there was a fermentation of a different kind, because he says: "Animal matters in general are more liable to decompose than vegetable

[1]Agricultural Chemistry, p. 269. [2]Ibid., pp. 272 and 273.

substances; oxygen is absorbed and carbonic acid and ammonia formed in the process of their putrefaction. They produce fetid compound elastic fluids, and likewise azote."[1]

The principal substances which are found in animal manures, according to Davy, are gelatin, fibrin, mucus, animal fats and oils, and albumin and urea. The effect of sterilization or pasteurization in preventing the decay of animal matters is fully recognized by Davy in describing what he calls "Appert's method of preserving animal and vegetable substances," which is practically the pasteurization of the present day. He says: "This method is by filling a vessel of tin plate or glass with the meat or vegetables; soldering or cementing the top so as to render the vessel air-tight, and then keeping it half immersed in a vessel of boiling water for a sufficient time to render the meat or vegetables proper for food. In this last process it is probable that the small quantity of oxygen remaining in the vessel is absorbed; for on opening a tinned iron canister which had been filled with raw beef and exposed to hot water the day before, I found that the minute quantity of elastic fluid which could be procured from it was a mixture of carbonic-acid gas and azote."[2]

It appears, therefore, that the process of pasteurization is at least as old as the nineteenth century.

Sir Humphry makes the following additional observation: "Where meat or vegetable food is to be preserved on a large scale for the use of the navy or army, for instance, I am inclined to believe that by forcibly throwing a quantity of carbonic acid, hydrogen, or azote into the vessel by means of a compressing pump, similar to that used for making artificial seltzer water, any change in the substance would be more effectually prevented. No elastic fluid in this case would have room to form by the decomposition of the meat, and the tightness and strength of the vessel would be proved by the process. No putrefaction or fermentation can go on without the generation of elastic fluid, and pressure would probably act with as much efficacy as cold in the preservation of animal or vegetable food."[2]

The use of oil cakes for fertilizing is recommended by Davy, and rape cake and linseed oil are mentioned, although the knowledge that their value depends upon their nitrogenous bodies did not obtain. The fertilizing value of malt dust, which consists of the powdered radicle of malt, is attributed to the amount of sugar which it contains. Linseed cake is said by Davy to be too valuable as a food for cattle to be employed as a manure. Seaweed is also recommended as a valuable fertilizing material. He also dwells upon the value of wood ashes, animal carcasses, and fish for fertilizing purposes. The value of fish is explained by Davy as follows: "It is easy to explain the operation of fish as a manure. The skin is principally gelatine, which, from its slight state of cohesion, is readily soluble in water;

[1] Agricultural Chemistry, p. 274. [2] Ibid., pp. 278 and 279.

fat or oil is always found in fishes, either under the skin or in some of the viscera, and their fibrous matter contains all the essential elements of vegetable substances."[1]

The curious idea that the oil is the chief manurial substance is further advanced in the statement that blubber is a valuable manure. Probably the real value of the blubber was from the minute quantity of nitrogen which it contained.

The value of bones is recognized by Davy. It is stated that "the more divided they are the more powerful are their effects." Bone dust and bone shavings, according to Davy, may be advantageously employed, and he recognizes that the basis of bone is the phosphate of lime, and also that it contains gelatin and cartilage, which seem to be of the same nature as coagulated albumin. It is evident that horn appeared to Davy to be a more powerful manure than bone. The refuse of the slaughterhouses, as skin, leather, hair, feathers, and blood, were regarded as valuable by him.

The value of guano as a fertilizer was also fully recognized at the beginning of the century, a much earlier date than is generally supposed. Davy says that "the value of guano as a fertilizer is easily inferred from its composition. It contains one-fourth part of its weight of uric acid, partly saturated with ammonia and partly with potassa, some phosphoric acid and lime, and small quantities of sulphate and muriate of potassa, and a little fatty matter."[2]

The value of lime for fertilizing purposes is fully discussed by Davy and the principles of its application most justly set forth.[3]

Magnesia was supposed to have almost equal value. The value of gypsum was also thoroughly appreciated. The use of ashes of burned peat was said to be very beneficial.

The value of phosphorus as a plant food was not appreciated, even at the time of Davy, and no large deposits of mineral phosphates were known. In speaking of phosphate of lime, he says: "It exists in some places in these islands native, but only in very small quantities. * * * It is probably necessary to corn crops and other white crops. * * * Bone ashes ground to powder will probably be found useful on arable lands containing much vegetable matter, and may perhaps enable soft peats to produce wheat; but the powdered bone in an uncalcined state is much to be preferred in all cases when it can be procured."[4]

Davy thus unwittingly shows the great loss of fertilizing matter which attends the burning of bones by the destruction of the nitrogenous bodies which they contain, but was not aware that this loss diminished their utility. Speaking of wood ashes, he says: "Wood ashes consist principally of the vegetable alkali united to carbonic

[1] Agricultural Chemistry, p. 289.
[2] Ibid., p. 297.
[3] Ibid., pp. 315 *et seq.*
[4] Ibid., p. 336.

acid, and as this alkali is found in almost all plants, it is not difficult to conceive that it may form an essential part of their organs."[1]

The vegetable alkali referred to is potash, and its efficiency was supposed to be due to the fact that it rendered soluble carbonaceous and other substances and permitted them to be absorbed by the tubes in the radicle fibers of plants.

In regard to soda, which he calls "mineral alkali,"[2] in distinction from vegetable alkali, he regards it of equal value. The use of common salt is also urged, because it is offensive to insects.

The observations made by Davy on the use of nitrate of potash are extremely interesting. He says: "Sir Kenelm Digby states that he made barley grow very luxuriantly by watering it with a very weak solution of niter; but he is too speculative a writer to awaken confidence in his results. This substance consists of 1 portion of azote, 6 of oxygen, and 1 of potassium, and it is not unlikely that it may furnish azote to form albumen or gluten in those plants that contain them; but the nitrous salts are too valuable for other purposes to be used as manures."[3] This is a very apropos observation, since it was made at the time of the Napoleonic wars.

Sulphate of potassium, Davy says, is considered a valuable manure by Dr. Home. Mr. Naismith questions his results, and quotes experiments hostile to his opinion, and, as he conceives, unfavorable to the efficacy of any saline manure.[3]

In a general view of the whole subject of the use of saline substances, Davy says:

> It is unnecessary to discuss to any greater extent the effects of saline substances on vegetation, except the ammoniacal compounds, or the compounds containing nitric, acetic, and carbonic acid; none of them can afford by their decomposition any of the common principles of vegetation—carbon, hydrogen, and oxygen.
>
> The alkaline sulphates and the earthy muriates are so seldom found in plants, or are found in such minute quantities, that it can never be an object to apply them to the soil. It was stated in the beginning of this lecture that the earthy and alkaline substances seem never to be formed in vegetation, and there is every reason, likewise, to believe that they are never decomposed, for after being absorbed they are found in their ashes.[4]

It is thus seen that as late as 1815 there was no practical appreciation of the use of mineral fertilizers, even in the most advanced studies of the relation of chemistry to agriculture, and the notions regarding the application of vegetable and animal matters for fertilizing purposes were in most cases erroneous and the knowledge of their good effects principally empirical.

KNOWLEDGE OF THE COMPOSITION OF AGRICULTURAL CROPS.

All that was practically known at the beginning of the century in regard to the chemical composition of agricultural products is contained in the third lecture given by Sir Humphry Davy before the

[1] Agricultural Chemistry, p. 337.
Ibid., p. 337.
[3] Ibid., p. 339.
[4] Ibid., p. 340.

British Board of Agriculture.[1] It will not be necessary, therefore, to give the opinions of other authors on this subject.

Vegetables are thus defined: "Vegetables are living structures distinguished from animals by exhibiting no signs of perception or of voluntary motion; and their organs are either organs of nourishment or of reproduction; organs for the preservation and increase of the individual, or for the multiplication of species."

Nineteen different bodies or classes of bodies were recognized by Davy as constituting vegetable substances in general. These are: "1, gum, or mucilage, and its different modifications; 2, starch; 3, sugar; 4, albumen; 5, gluten; 6, gum elastic; 7, extract; 8, tannin; 9, indigo; 10, narcotic principle; 11, bitter principle; 12, wax; 13, resins; 14, camphor; 15, fixed oils; 16, volatile oils; 17, woody fiber; 18, acids; 19, alkalies, earths, metallic oxides, and saline compounds."

Gum, or mucilage, which is a certain variety of gum, is described as being easily soluble in water and insoluble in alcohol. All the varieties of gum and mucilage were regarded as valuable plant foods, as well as useful in some of the arts, as, for instance, in calico printing.

Starch is described as being soluble in boiling water.

Sugar is regarded as furnished chiefly by the sugar cane, and only small quantities by other sources. It is remarkable that Davy describes a method, which he proposed for purifying raw sugar, which has lately been made the subject of patents in this and other countries, namely, by washing the crystals, or raw sugar, with a sugar sirup. The sugar which is derived from the beet is said to be peculiar in its nature and to agree with the sugar of grapes in its general properties and in having a bitter taste. The properties of sugar, as an animal food, were recognized by Davy, who states that the British market was overstocked with this article from the West India Islands, and for this reason proposals had been made for using it as a food for cattle. His opinion that it was a valuable food for vegetables has already been cited.

Vegetable albumin was known to exist in the juice of the papaw tree, and tables of analyses are given showing its percentage composition.

The properties of gluten are described, and it is said to be distinguished from albumin chiefly by its insolubility in water. Its high nutritive value was also appreciated, and it is stated to be one of the most nutritive of vegetable substances.

Under the head of "extract" is described a variety of substances obtained from different plants, evidently mixtures of various bodies. Extract, it is said, in its pure form can not be used as an article of food, but it is probably nutritive when united to starch, mucilage, or sugar.

Tannin is declared to be of no nutritive value.

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[1] Pages 55 *et seq.*

The other bodies found in plants, as enumerated by Davy, are of no value, from a food point of view, except the oils, which he divided into two varieties, namely, fixed and volatile.

Among the acids which were known to exist at that time in the vegetable kingdom, are mentioned oxalic, citric, tartaric, benzoic, acetic, carbonic, and prussic.

Of the fixed alkalies, potash is recognized as being the one common to the vegetable kingdom.

Of the mineral acids, Davy states that phosphoric, sulphuric, muriatic, and nitric exist in many saline compounds in the vegetable kingdom, but they can not be properly considered as vegetable products.

Davy held to the opinion, which was prevalent in his time, and which still exists in many quarters, that the rigidity of plants is due solely to the quantity of silica which they contain. His views of the composition of plants were the most advanced and scientific which had ever at that time been proposed, and their scientific value especially may be recognized by a comparison with the theory of plant composition exposed by Dr. Thomson in his elaborate and learned system of chemistry. He quotes Thomson as describing six vegetable substances, which he calls mucus, jelly, sarcocol, asparagin, inulin, and ulmin. Davy does not agree with this view, and says: "It is probable, from the taste of sarcocol, that it is gum combined with a little sugar. Inulin is so analogous to starch that it is probably a variety of that principle; ulmin has been lately shown by Mr. Smithson to be a compound of a peculiar extractive matter and potassa; and asparagin is probably a similar combination."[1]

It is not to be wondered at that the views, even of the most advanced kind, concerning the composition of plants were of such an erroneous nature when we consider the state of analytical chemistry at that time. Sir Humphry Davy was, without doubt, the most skillful and accurate chemist of his time or of any time that preceded him, and the wonder is that he could have reached such correct results with the methods of analysis which he himself describes.

In regard to the theoretical composition of bodies resembling each other in vegetable substances, Davy says:

> Gum and sugar afford nearly the same elements by analysis, and starch differs from them only in containing a little more carbon. The peculiar properties of gum and sugar must depend chiefly upon the different arrangement or degree of condensation of their elements; and it would be natural to conceive from the composition of these bodies, as well as that of starch, that all three would be easily convertible one into the other, which is actually the case.
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> At the time of the ripening of corn the saccharine matter in the grain and that carried from the sap vessels into the grain, becomes coagulated and forms starch; and in the process of malting, the converse change occurs. The starch of grain

[1] Third lecture by Sir Humphry Davy before the British Board of Agriculture, p. 118.

is converted into sugar. As there is a little absorption of oxygen and a formation of carbonic acid in this case, it is probable that the starch loses a little carbon, which combines with the oxygen to form carbonic acid; and probably the oxygen tends to acidify the gluten of the grain, and thus breaks down the texture of the starch, gives a new arrangement to its elements, and renders it soluble in water.[1]

The first table showing the comparative nutritive value of different foods ever published was probably that constructed by Davy, in which all the more common vegetable varieties of foods are compared in respect of their proportions of nutritive matter. These nutritive bodies are grouped under four heads—mucilage, or starch; saccharin matter, or sugar; gluten, or albumin; and extract. Rather strangely, the oils and fats of vegetables are not regarded as of sufficient nutritive importance to find a place in the table.

The value of gluten in bread making is fully recognized in Davy's studies of the composition of plants, and some of the earliest observations upon the nutritive value of different kinds of wheat are found in his writings. He says:

It is probable that the excellence of the different articles as food will be found to be in a great measure proportional to the quantities of soluble or nutritive matters they afford; but still these quantities can not be regarded as absolutely denoting their value. Albuminous or glutinous matters have the characters of animal substances; sugar is more nourishing, and extractive matter less nourishing, than any other principles composed of carbon, hydrogen, and oxygen. Certain combinations likewise of these substances may be more nutritive than others.[2]

It was also recognized that flour made from hard wheat is to be more esteemed than that made from soft, even when there is no difference in the process of making them into bread; but the flour from hard wheat will absorb and retain more water in making into bread, and will consequently produce a greater weight of bread. It is shown by chemical analysis that this difference in incorporating hard and soft wheat in bread making is due to the larger amount of gluten contained in the hard wheat.

REVIEW OF THE EARLY KNOWLEDGE OF THE RELATION OF CHEMISTRY TO AGRICULTURE.

It is now possible to give a general view of the knowledge of the relations which chemistry held to practical agriculture at the beginning of the century. In regard to soils, some general notions of a true character were held as to their composition. The real plant foods in the soil, however, were not appreciated. While in a general way it was recognized that phosphoric acid, potash, and lime entered into the composition of the plant, it is evident from a study of the literature of the time that silica was regarded as more beneficial to the plant than any of the other mineral matters mentioned. The manner in which the food was furnished to the plant was imperfectly

[1] Third lecture by Sir Humphry Davy before the British Board of Agriculture, pp. 127 and 128.

[2] Ibid., p. 151.

known, save that it was generally conceded that the mineral matters must first enter into solution before they could be distributed throughout the plant.

In regard to the physical nature of the soil, it was a matter of common observation that it had much to do with the efficacy of plant growth. The open and porous soils were more prized than those of a hard and impenetrable nature, and the general distinctions between sandy, loamy, and clayey soils were well understood.

The notion was extremely prevalent that the soils serve more as a resting place and support for the root system of the plants, while the materials for plant growth in some way resemble exudations, or emanations, which come partly from the soil itself and partly from the atmosphere. The actual chemical composition of soil was but little understood, and this arose from the fact that the means of chemical analysis were so meager and its processes so unsatisfactory as to preclude the possibility of securing exact data. Nevertheless, a reasonably accurate knowledge was had of the chief constituents of the soil, if not of the functions which they played in plant growth. That the soil was a vehicle for the administration of the nourishing elements of food, was not fully appreciated at the beginning of the century. The nitrogen, or azote, as it was called in that day, was supposed to reach the plant exclusively in the form of ammonia, and no accurate knowledge of the relation of the soil to the production of azotized foods was extant.

Perhaps, however, the most striking error in connection with the notions relating to the constitution of the soil itself in respect of plant growth is found in the fact that the true functions of phosphoric acid and potash in the nutrition of plants were imperfectly, if at all, understood by even the most advanced agricultural chemists of that day.

It is true that the chemical composition of manures which were then in use was not well known, nor were the processes by which manures became available as plant food at all understood, but the practical knowledge of the use of stable manures, of marls, of gypsum, and of lime was generally diffused and acted upon. Of artificial manures, other than those mentioned, little was known save that the aborigines of the New England States had taught the early settlers the great value of using fish as a fertilizer.

Some idea also was entertained of the value of the refuse of the slaughterhouses for fertilizing purposes, and it was known that blood, bone, and horn were useful in promoting the growth of crops, but how and why were not understood.

The value of clover and other leguminous crops in increasing soil fertility was recognized, but the causes which established this value were not at all known. The process of fermentation was recognized in the manufacture and preparation of manures, but the nature of this fermentation was wholly unknown to the investigators and chemical agriculturists of that time. Empiricism in the use of manures through thousands of years had led to most valuable practical results, but little was due at that time to the discoveries and researches of chemistry. When we look at the knowledge which was possessed of the composition of plants, we do not wonder that the relations of the soil and of fertilizers to plant growth were so little understood. The methods of investigation in vogue were totally inadequate to reveal the true constitution of plants, and it is a matter of wonder to us at the present time that with such crude apparatus and such imperfect methods so much accurate knowledge could have been obtained. The processes of organic analysis had only just been introduced, and only the general constitution of the carbohydrates, as represented by the gums, mucilages, starches, and sugars of that day, was definitely established, but the percentage of nitrogen contained in the albumin and gluten recognized as existing in plants is scarcely more accurately known at the present day than it was then.

The more important organic acids also existing in plants had been discovered, separated, and identified, and in general it must be confessed that, in so far as the progress of chemistry relating to the composition of plants is concerned, the agricultural chemists of the beginning of the century are to be congratulated on the attainments which they had made. The weak point of their researches and investigations was that they had made no systematic effort to correlate the composition of plants and of the soil to the principles of plant growth. With their imperfect ideas of the nature of plant nutrition, it did not occur to them that a great system of scientific agriculture could be based upon investigations of this kind. They, however, had done enough to pave the way for the great impetus which the investigations of Liebig, Gilbert, Boussingault, and others gave to systematic agricultural chemistry some thirty or forty years later.

Scientific Agriculture About the Middle of the Century.

THE ERA OF LIEBIG.

The publication of Liebig's work entitled "Chemistry in its applications to agriculture and physiology," in 1840, marked a complete change in the theories of chemistry in respect of agriculture existing at the beginning of the century as portrayed in preceding pages, and inaugurated the new science of agriculture, resting upon his investigations as a foundation. If Wurtz could say, "Chemistry is a French science, founded by Lavoisier, of immortal memory," with all the greater propriety may we say of the agriculture of to-day, "Agriculture is a chemical science, founded by Liebig, of immortal memory." "Perfect agriculture," Liebig says in the preface to the first edition of his book, "is the true foundation of all trade and industry; but a rational system of agriculture can not be formed without the application of scientific principles, for such a system must be based on an exact acquaintance with the means of nutrition of vegetables and with the influence of soils and actions of manure upon them; this knowledge we must seek from chemistry, which teaches the mode of investigating the composition and of studying the character of the different substances from which plants derive their nourishment."

Within a year after Liebig's book was published it was translated into English, and soon thereafter was found in the languages of all the leading nations of the world. Liebig, however, must not be given the sole praise for the establishment of the true theory of scientific agriculture. Very much earlier in the century De Saussure, a celebrated French chemist and botanist, published his "Chemical researches on vegetation," and a decade before Liebig published his first work Boussingault, the most celebrated French agricultural chemist of the early part of the century, had produced a great many works on the relations of chemistry to agriculture. To both of these authors Liebig is largely indebted, and to each of them he gives full credit. The part which Davy took in preparing the way for these later investigations has already been pointed out.

Previous to the time of Liebig, as already indicated, it was commonly understood that organic substances, such as sugars and oils, were the chief foods of plants, either in the fresh state or in the partially decayed condition known as humus. In fact, the attitude of chemistry toward agriculture in the first four decades of the century was so strongly marked on this point that the whole system of plant nutrition, as understood at that time, might with propriety be designated the humus theory. Although other writers before the time of Liebig had intimated that the air and water, and not the earth, were the source of the carbon, oxygen, and hydrogen in plants, it must be admitted that it was through the researches of Liebig that the great principles of plant nutrition, founded on the elaboration of the elements of carbohydrates from the air and water, were fully developed. As in most other instances, however, the tendency of mankind to reach extremes was shown on this point. Liebig in his fight against the humus theory naturally went to the other extreme of denying that the humus took any part at all in plant nutrition. He based his chief objection to the humus theory on the ground that humus was practically insoluble, and that therefore it could not enter into the circulation of the plants. This argument we know now is not a valid one, but it served as the basis of an attack upon an erroneous theory which had established itself firmly in the minds of advanced agriculturists.

As early as 1807 Thompson observed that if plants be deprived of carbonic acid, they wither and die, and these observations had been confirmed by a great many observers. It was Ingenhousz who first made the observation that plants absorb carbonic acid only under the influence of sunlight, while in darkness the tendency of plants is to give off rather than absorb this gas. It was urged against Liebig's theory of plants deriving their carbon from carbonic acid that the quantity of this gas in the air was so minute as to render Liebig's idea absurd. It is well known at the present time that the amount of carbonic acid in the air does not much exceed 4 parts in 10,000, and yet this quantity is amply sufficient to furnish the immense quantities of carbon of which the structures of plants are largely composed. It is easy to believe that in past ages, especially the one known by geologists as the Carboniferous Era, the quantities of carbonic acid in the air were much larger than at the present time and the amount of precipitation much greater. These two conditions, combined with the fact that the temperature of the earth must have been higher, account for the luxuriant growth of vegetable matters in those epochs, the gradual decay of which, under pressure, has provided the coal deposits of the present day. Liebig and his colaborers finally determined experimentally that organic matters were not suitable foods for plants, and that when sugar, gum, or starch are offered to a plant these compounds do not nourish it in any true sense. The vital functions of plant life consist rather in the elaboration of these organic bodies and other compounds from the inorganic elements on which the plants are fed. This is true, especially of green plants; whereas in the case of colorless plants the reverse is probably true, and these feed rather upon organic matter than upon inorganic. It was in this instance that Liebig's theory led him too far in denying the part of organic matter in any kind of plant life. Indeed, it has been found by researches carried on in the Division of Chemistry that the elements of humus may enter into the plant, as shown by the dark color of the juices of sugar cane grown upon humus soils and in the increase of amid nitrogenous matter in oats grown upon soils extremely rich in humus.

Long after the establishment of the practical truth of the doctrines of Liebig it was discovered that Lavoisier, fully sixty years before the time of Liebig's discoveries, had observed the same phenomena, although the information was not given to the public until the final publication of the papers of the great French chemist in 1862. It was then discovered that in one of Lavoisier's notes he had made this pregnant observation: "Plants derive the materials necessary for their formation from the air which surrounds them, from the water, and in general from the mineral kingdom." Thus, after all, we must attribute to Lavoisier the credit of having discovered the true theory of plant nutrition. The following from Lavoisier's observations wonderfully increases our admiration for the genius of this great man:

Animals feed on plants and on other animals fed by plants, so that the substances composing them are, in the last instance, always drawn from air and from the mineral kingdom. On the other hand, fermentation, putrefaction, and combustion continually restore to the air and to the mineral kingdom the principles borrowed from them by plants and animals.

While the theory of Liebig touching the formation of carbohydrates is fully corroborated by all modern investigations, in so far as the food of green plants is concerned, he never obtained the true solution of the method in which nitrogen was fed to plants. He assumed that the nitrogen was fed in the form of ammonia produced by the putrefaction of plants and animals, and, as is now well known, formed in the atmosphere by electrical discharges and in other ways. Liebig, as appears from his researches, was not at first aware of the importance of the part played by artificial fertilizers and manures in furnishing nitrogen to plants.

MINERAL THEORY OF PLANT NUTRITION.

The advances which chemistry has made in establishing the methods by which nitrogen becomes food for plants will be shown later. While the older view of the nutrition of plants is properly characterized by the term "humus," or "organic," theory, the school established by Liebig held to the theory of plant nutrition which may properly be denominated the "mineral" theory. Liebig was the first to study systematically the subject of mineral or artificial manures, and his views in this matter soon found their way into the United States. In the agricultural part of the Patent Office Report for the year 1845 Liebig contributes an interesting letter on the subject of artificial manures. In this letter it is believed the true principles connected with artificial manuring were first brought to the attention of American farmers. Among the artificial manures mentioned by Liebig in this letter are the earthy phosphates, of which at that time practically only one variety, namely, apatite, was known to exist. Liebig, however, in discussing the value of phosphate of lime as a fertilizer makes the curious mistake of saying that bones are most efficient for fertilizing purposes after they have been burned. It is strange that so keen an observer as Liebig could have been led into such a great error. He was right, however, in assuming that so far as the phosphate of lime is concerned, its utility as a plant food is determined largely by the rapidity with which it will enter into solution. It was for this reason that he assumed that the burned bones were more efficient than the unburned, arguing with great skill that the gelatin, or glue, which the bones contained had a tendency to keep the phosphatic material insoluble. He was the first who recommended the use of sulphuric acid on bones and mineral phosphates for the purpose of converting the lime into gypsum and securing the phosphoric acid in a state more easily soluble and assimilable. He also recommended the alkaline phosphates, such as those of soda and potash, as being excellent fertilizing substances on account of their high solubility. He recognized that the alkalies, namely, potash and soda, should be constituents of every rationally composed manure, since by them the original fertile condition of the fields is preserved. He observed that the soil which contains alkalies in too small a quantity may be fertile for grain, but not necessarily so for turnips or potatoes, which require a great quantity of alkali. Sulphate of potash, common salt, and chlorid of potash were regarded as valuable manures, and the latter was said to be found in milk in large proportions.

Gypsum is recommended as a nourishment for leguminous plants. In speaking of the salts of ammonia, Liebig says it is certain that the azote, or nitrogen, of the plants is derived from the ammonia of the atmosphere or from a manure which is provided in the shape of animal fluid and solid excrement, and, further, that nitrogenous bodies are only useful in plant nutrition in proportion as they give up their nitrogen in the form of ammonia. In regard to decaying vegetable matters, he regarded them as useful only in so far as by their decay they afforded carbonic acid, but says that they are not indispensable in manure. As before mentioned, Liebig rather inclined to the extreme view in this case, denying to humus matters any proper place in plant nutrition. He fortifies the observations made by citing analyses of the ashes of some common crops, such as beans, peas, potatoes, clover, and hay. He also deduces the conclusion from these analyses that for stalks and leaves, manurial elements are required other than for seeds. The stalks and leaves contain no alkaline phosphates, but they require a rich supply of alkaline carbonates and sulphates. On the other hand, the carbonates are entirely wanting in the seeds, but the latter are very rich in phosphates. It is rather curious that Liebig should have fallen into the error of supposing that the carbonates in the ash existed in this state in the plants themselves; that he did not know that the occurrence of carbonates in the ash of the leaves and their nonoccurrence in the ash of the seeds are due solely to the presence of peculiar constituents of each, which permit a formation of carbonates on combustion in the ash of the leaves and prevent its formation in the ash of seeds on account of the excess of phosphoric acid, which at a high temperature completely expels carbonic acid from combination. In his letter to American farmers he calls particular attention to the fact that a manure which furnishes only one constituent element of plant food may rapidly exhaust the soil of all the other elements of fertility, and hence the necessity of supplying complete fertilizers instead of partial ones where the fertility of the soil is to be preserved or increased. He ascribes the fact that guanos have not always met the expectation of those who have used them to the presence in them of ammonia and alkaline phosphates and the practical absence of alkalies. He therefore urged particularly that fertilizers containing large quantities of potash and soda be used in conjunction with guanos in order to secure the best effects. In this letter Liebig also calls attention to the loss of the soluble elements of manure by lixiviation in the soil, and for this reason recommends that the manure of the barnyards be preserved, either in pits from which the water can not escape or in covered sheds, to prevent the exhaustion of their soluble fertilizing ingredients. He says:

> The reason why in certain years the influence of the best and most plentiful manuring is scarcely perceptible is that during the moist and rainy springs and summers the phosphates and other salts with alkaline bases, as also the soluble ammoniacal salts, are entirely or partly removed. Art must find out the means of reducing the solubility of the manuring substances to a certain limit; in a word, of bringing them into the same state in which they exist in a most fertile virgin soil, and in which they can best be assimilated by plants.

Looking forward, too, with a prophetic eye, Liebig saw a great industry which would grow out of his researches in the establishment of factories where artificial manures would be prepared for agricultural uses. He says at the close of his letter:

> Manufactories of manure will be established in which the farmer can obtain the most efficacious manure for all varieties of soils and plants. Then no artificial manure will be sold whose exact amount of efficacious elements is not known, and this amount will be the scale for determining its value. Instead of the uncertainty of mere empiricism, all the operations of agriculture will be carried on with certainty, and instead of awaiting the results of our labors with anxiety and doubt, our minds will be filled with patience and confidence.

In reading over this admirable letter, contributed by request of the Commissioner of Patents to the American farmers by Professor Liebig, we are struck with the fact that fifty-five years ago the farmers of this country were provided with a creed for judging fertilizing materials which has undergone but little change as the result of all the researches which have been made since that time. It is hardly to be expected that even Liebig at that day would have correctly appreciated all the problems connected with fertilizing processes. The great principles, however, which underlie the application of artificial fertilizers were fully set forth, and the publication of this information to American farmers is therefore justly considered an epoch in the relations of chemistry to agriculture in the United States.

Although the views of Liebig were first promulgated in 1840, and, as indicated, were placed before the farmers of America as early as 1845, we find that as late as 1848 grave doubts of their accuracy were still entertained by those in charge of the Agricultural Division of the Patent Office. In the report for 1848 there is a long article, beginning on page 195, in which the views of Liebig are vigorously combated by references to authorities of his own country, chiefly von Thaer and Schulze. Sir Humphry Davy is held up in this discussion as an authority of greater value than Liebig. Considerable space is given to showing that it is quite improbable that the air, however rapidly it may move, can furnish enough carbon for the use of the plants; and Professor Schleiden, in his criticism of Liebig's theory, says: "Must we here adopt the ignorance of physics, or a wholly thoughtless insertion of it, as a cause of this monster of the wind theory?" It is concluded from a very elaborate study of the various theories relating to the nutrition of plants that Liebig's theory is liable to some fundamental objections, and the question is raised whether the humus theory, of which von Thaer was the chief apostle, supported, however, by the eminent authority of Professor Schulze, could be maintained against the objections which Liebig had urged to it. The Commissioner of Patents adds:

It may be thought by some we have devoted too much time and space to this subject, but Liebig's works have been so extensively diffused in this country and in their charm of style and the enthusiasm with which the author entered into his discussions, the boldness displayed in his enunciation of his novelties, and other concurrent causes, they have exerted so great an influence in various sections that these facts seemed to justify the attempt to present, in as condensed a form as we could with any justice to the author, one of the ablest criticisms to which his principles have been subjected. Having in former reports presented the history of Liebig's views, we may claim the right of giving, too, the other side of the question, and the more so since a right discrimination of the points is contained in the foregoing synopsis of Professor Schulze's elaborate criticism.

It is evident, therefore, that even at this time, almost the middle of the century, the view was still stoutly maintained by eminent men that the organic matters of which plants are composed were derived chiefly from the soil, and not from the atmosphere and water. Hence it was, that with wonderful pertinacity the agricultural chemists clung to the theory that the organic matters of plants were directly derived from the decaying organic matters of the soil, and that therefore humus was the chief element in the nourishment of plants. (Pls. IV and V show portraits of some of the early and of the more recent workers in agricultural chemistry mentioned in this paper.)

RELATIONS OF CHEMISTRY TO AGRICULTURE AT THE PRESENT TIME.

METHODS BY WHICH RESULTS OF CHEMICAL STUDIES HAVE BEEN MADE OF PRACTICAL USE.

Among the methods which have been chiefly instrumental in bringing the results of chemical research into practical use in agriculture at the present time may be mentioned the following:

(1) The teaching of agriculture in schools, colleges, and universities, and instruction given in farmers' meetings.

(2) The activity of agricultural colleges and experiment stations.

(3) Instruction in the relations of chemistry to agriculture given in the agricultural press.

TEACHING OF AGRICULTURE IN SCHOOLS, COLLEGES, UNIVERSITIES, ETC.

It is rather difficult in discussing the first of these subjects to determine when the first instruction was given in schools, colleges, or universities in regard to the relations of chemistry to agricultural science. The first professorship evidently established for this purpose was founded at the University of Halle in 1727, when Frederick William, King of Prussia, established a professorship of rural economy,

SOME EARLY WORKERS IN AGRICULTURAL CHEMISTRY.

in which the relations of chemistry to agriculture, as then understood, were developed and taught. The order in which similar chairs were established in other universities is hard to say, but in 1800 it is certain that other universities in Europe had followed the example of that of Halle.[1]

The importance of agricultural education was early recognized in the United States, as is seen in the Agricultural Reports of the Patent Office. In the report for the year 1847 a special plea is made for the establishment of agricultural education in the United States, as follows:

> We might remark on the application of chemistry, animal and vegetable physiology, geology, and other sciences, with domestic economy, in reference to this great question of progress and as elements not without their bearing on the development of our agricultural resources. But these topics may be better touched upon in another part of this report, where we may treat of modes of cultivation and feeding of animals, with kindred topics.
>
> There is one particular, however, which seems to claim our notice. This is *agricultural education;* a new era seems, in this respect, to be opening upon us. It may take years before we shall have our Hohenheims, Schliesheims, Tharands, and Moeglins, as in Germany and Prussia, but a beginning is made by attempts to establish such schools and colleges. There have been a number of the former set in operation by private enterprise, and in several of our colleges professors have been appointed who are well qualified to lecture on these subjects. In the time-honored universities of Harvard and Yale, two gentlemen who have enjoyed ample opportunities of pursuing their studies in Europe fill the chairs of the professorships. A man of experience also in science has recently been placed in this department in one of the colleges of Ohio. Much may be expected from the influence of these and similar positions in relation to this important subject; and here, too, we may refer our readers to the account given of agricultural education as well as of the agricultural convention at Breslau, by C. L. Fleischmann, esq. This account, with other articles of deep interest to the agriculturist of the United States, may be found in Appendix No. 1.

It is thus seen that more than half a century ago several agricultural schools, pure and simple, were established in Europe, and that at least two of the leading universities of this country, namely, Harvard and Yale, had established chairs of agricultural chemistry.

In the same report it is urged that traveling lecturers could diffuse agricultural knowledge, and the custom of the farmers' clubs and agricultural colleges of Great Britain in bringing together distinguished scientific men to give their views upon some topic selected as the subject of discussion is mentioned with favor. It is stated that the lectures of this kind indicate the principles of the application of manures, and deal with many other questions in which a knowledge of chemistry plays an important part.

In the article of Mr. Fleischmann, in the same report, on the agricultural schools of Germany, an account is given of his visit to one of the earliest and most famous of these schools, namely, that founded

[1] Rural Socrates, p. 15.

and conducted by von Thaer. In this school Dr. Trommer, a celebrated chemist of his time, was employed as a lecturer on chemistry and physical philosophy with reference to their employment in agricultural industry. On page 319 of the report it is stated that the lectures of Dr. Trommer were especially devoted to agricultural chemistry, illustrated by experiments required for a clear insight of the same, with constant regard to the use of these sciences in agriculture and the business therewith connected, such as breweries and distilleries, sirup and sugar making from beets and potatoes, and other matters of a technical nature relating to agriculture. Besides this, the student was given an opportunity of performing simple chemical analyses under a superintendent. There was also taught the outline of the physiology of plants, thus enabling the educated agriculturist to penetrate deeper into the science and to secure a clearer insight into vegetation.

Thus early it is seen that agricultural chemical technics, and the principles upon which they are based, were made a principal part of the instruction given in agricultural schools to the young man engaged in acquiring a knowledge of agricultural science.

Space will not allow the tracing of the evolution of agricultural education step by step, and so we must pass over the early history and proceed to the consideration of the practical foundation of such education in the United States.

The first endowment for teaching agriculture in the United States was provided for Harvard University in 1837 by the will of Benjamin Bussey, and for Yale in 1846, and the first instruction in agricultural science from a chemical point of view was given at Yale in 1847. Since that time chairs of agricultural chemistry have been regularly established and maintained in these institutions.

RÔLE OF CHEMISTRY IN THE AGRICULTURAL COLLEGES AND EXPERIMENT STATIONS.

In a study of the impress which chemical research has made upon agriculture, there has been no factor during the past twenty years which can compare with the work of the agricultural experiment stations of the United States. Richly endowed as they are by the General Government, they have had every opportunity to secure the best results for practical agriculture.

In this work chemical science has played a very important part in the furthering of agricultural prosperity. Of the forty-nine directors of the stations at the present time, twenty were professional chemists at the time of their appointment. The selection of so many professional chemists was no mere chance, but evidently had some relation to the dominant position which the science of chemistry held to the promotion of agricultural chemical research. The list of directors of the agricultural experiment stations of Germany shows the same condition of affairs.

The great influence of chemistry on the agricultural experiment stations of this country is not measured alone by the number of professional chemists which is found in the directorates, but also in a comparison of this number to that of other scientific men holding similar positions. Very few of the other sciences are represented among the directors of stations, and no one of them can compare in its number of representatives to the science of chemistry. Among the working forces of the stations chemists also predominate. There are twice as many chemists employed in the stations as there are men engaged in any other professional scientific work. Statistics show that the number of chemists employed in the agricultural experiment stations of the United States is one hundred and fifty-seven, while the number of botanists is fifty and the number of entomologists forty-two. The number of employees belonging to other branches of science is very much less than that of the botanists and entomologists, and the total number of scientific men employed in all other branches of scientific work in the stations does not greatly exceed, even if it be equal to, the number of those employed in chemical research alone.

While dwelling upon the predominance of professional chemists in the directorate and upon the staff of the experiment stations it seems eminently proper to mention here in a special manner some of the earlier eminent chemists who have contributed so much to the value of chemical research in our agricultural colleges and experiment stations. Among these must be mentioned Prof. F. H. Storer, of Bussey Institute (Massachusetts), who first began the regular publication of a bulletin recording the work of the school and station, which has "set the step to which the bulletins from many other stations are still marching." The bulletins of the Bussey Institute describing original research work on agricultural subjects have proved of the highest benefit to agriculture. Professor Storer's work entitled "Chemistry in some of its relations to agriculture," the first edition of which was published in 1887, has had a marked effect upon agriculture in this country.

As early as 1846 Yale University, then called Yale College, appointed a professor of agricultural chemistry. This was John Pitkin Norton, who had devoted himself to the study of scientific agriculture both in this country and Europe, especially with the celebrated Liebig. He brought to his position a ripe knowledge and wisely directed enthusiasm for agriculture, which he used with the greatest profit in its service. In 1855 Samuel William Johnson was appointed instructor in agricultural and analytical chemistry, and soon after full professor. Perhaps no one ever succeeded more fully in popularizing scientific agriculture than Professor Johnson. His two books, "How plants feed" and "How plants grow," the first editions of which were published in 1868 and 1870, respectively, have been kept abreast of modern progress in successive editions, and are still used as standard text-books and as authorities on the practical relations of chemistry to agriculture.

In the University of California the work of Prof. E. W. Hilgard must be mentioned as being of fundamental importance in the development of the relation of chemistry to agriculture in this country. Professor Hilgard in his classical work on soils has placed himself in the front rank of investigators on this subject, not only in this country but in the world, and his achievements have been recognized both by his countrymen and by the most celebrated societies of Europe. A knowledge of the soil and its relations to plant growth constitutes one of the fundamental principles of chemistry, and the researches of Professor Hilgard in this line have done much to place agriculture in the United States on a strictly scientific basis.

At Cornell, even before her doors were open to students, a professorship in agricultural chemistry was established. Prof. G. C. Caldwell was appointed to fill this position, and he has done so with distinction to himself and the university, and with the greatest benefit to agriculture. One of the most important services in connection with Professor Caldwell's labors at Cornell has been the publication of his work on agricultural chemical analysis in 1869. At that time no work of a similar nature existed in the English language, and Professor Caldwell's book was a veritable boon to students in agricultural science.

This brief reference to the contributions of some of the earlier workers in agricultural chemical science in this country would not be complete without mention of the labors of Prof. C. A. Goessmann, of the Massachusetts Agricultural College.

It is not possible in the space assigned to this paper to even name the more prominent later workers.

A national epoch in agricultural education in this country began with the passage of the Morrill Act, in 1862, establishing and endowing colleges where agriculture should be one of the principal branches in which instruction is given. An additional impetus was given to this great work in 1887 by the passage of the Hatch Act, establishing agricultural experiment stations in the several States. The organization lists of the agricultural colleges and experiment stations of the United States now show the great number of men working in the lines of agricultural chemistry. This most remarkable evolution of agricultural education has taken place practically within the last thirty years, and there is no country which can now be compared with the United States in the munificence of the endowment for agricultural chemical research or in the vast amount of research and experimental work conducted in these lines.

DISSEMINATION OF THE PRINCIPLES OF AGRICULTURAL CHEMISTRY THROUGH THE AGRICULTURAL PRESS.

One of the important channels through which the principles of agricultural chemistry have been disseminated throughout the United States has been the agricultural journals. In no other country has the agricultural press obtained so firm a hold and exercised such an authority as in this country. Early in the century agricultural journals were established, many of which are still in existence. In 1845 it is stated in the agricultural report for that year that there were twenty-six journals in the United States devoted exclusively to agriculture. Of these, eight were weekly, sixteen monthly, one quarterly, and one unclassified. Among those which are still in existence, and which were mentioned at that time, may be cited the Maine Farmer, the Boston Cultivator, the Massachusetts Ploughman, the American Agriculturist, the American Farmer, the Indiana Farmer, the Prairie Farmer, and perhaps a few others. A list of the agricultural journals of the present time would show a wonderful increase in number. In addition to the purely agricultural journals, a great many of the newspapers of the country have agricultural departments which, at least once a week, convey to the farmer important information in regard to scientific agriculture. It is evident, therefore, that many of the beneficial effects of chemical research relating to agriculture have found their application through the columns of the journals mentioned.

PROMOTION OF SCIENTIFIC AGRICULTURE BY THE ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS.

It is evident that one of the most important ways in which chemistry can promote the interests of agriculture is by furnishing reliable and accurate means of studying soils, agricultural products, and other bodies connected with the interests of farming. If researches of this kind are not made in a uniform way, they can not be compared among themselves, and if they are not made by accurate methods may lead to erroneous results. The full benefit of chemical research, therefore, on agricultural progress can only be secured when the methods of investigation employed are uniform and accurate. The condition of the methods of agricultural research in the United States up to within twenty years was not satisfactory. With the exception of the book by Professor Caldwell on "Agricultural chemical analysis," no distinctively American work had been done along these lines. To Professor Caldwell, scientific agriculture owes a great debt for being the first in this country to attempt to systematize the methods of chemical research as applied to agriculture. Nevertheless, this work had no official authority, and chemists engaged in agricultural research could use the methods described by Professor Caldwell or not, as they saw fit. The first steps toward correcting this condition of affairs were taken by the department of agriculture of the State of Georgia. Mr. H. J. Redding, now director of the experiment station of that State, induced Hon. J. T. Henderson, commissioner of agriculture of Georgia, to call a meeting of chemists interested in agricultural research, which was held in Washington City, at the Department of Agriculture, beginning July 28, 1880. This initial meeting, after making important advances, adjourned to meet in connection with the American Association for the Advancement of Science in August of the same year. An organization was perfected at this time, and it was again decided to meet with the American association in August, 1881, at Cincinnati.

Methods of analysis were agreed upon at these meetings, which, however, still lacked any official authority, as no permanent official organization had been effected. After the Cincinnati meeting no efforts were made to continue the meetings of the new organization, and it was felt that the personnel of the meetings had been of such a character as to render impracticable a harmonizing of the different conflicting elements represented. No further attempts, therefore, were made to coordinate the work of agricultural analysis until 1884, when a meeting of chemists connected with official agricultural work was held in May, at Atlanta, Ga. Here a strong organization was effected, and the meeting adjourned to Philadelphia in September. At the September meeting the organization of Official Agricultural Chemists was completed, admitting to full membership in the society all persons officially connected with agricultural research of a chemical nature throughout the United States, and to limited membership other chemists interested in agriculture having no official position. The constitution of the association provided that all methods of analysis which were adopted as official, and thus made binding upon its members, should be acted upon only by the votes of those who had official connection with chemical work, under government, either national or State. Since September, 1884, the Association of Official Agricultural Chemists has held annual meetings, mostly in Washington City, and, as a result, methods of research have been perfected and adopted which are made binding upon the members, and which have been recognized by the courts of the country as official in every respect. These methods of research have become so perfect and so effective that they have recognition in all countries, and the work of the association is everywhere recognized as being of the highest order and as having secured the greatest good. At the present time the official methods of investigation include not only the study of soils, of fertilizers, and of agricultural products, but special methods have been adopted for the study of human and animal foods, of dairy products, of different fertilizing elements, of manures and fertilizers in general, of carbohydrates and nitrogenous bodies, of tanning materials, and of insecticides.

The association has not contented itself with the mere study of analytical detail, but has instituted lines of research having for their object the elucidation of unsolved problems in agriculture and the application of the results to practical work. The direct practical benefit of the work of this association has been found in the establishment of efficient fertilizer control in nearly all of the States of the Union. By means of this official control the farmers are protected in the character of the fertilizing materials which they buy. These materials are inspected by the State authorities, and can only be sold when their composition comes up to the standard set by these authorities. The economical value of this control alone is only to be measured by millions of dollars. The association has published the results of its labors in numerous bulletins under the patronage of the Secretary of Agriculture and issued from the Division of Chemistry. These bulletins contain not only the proceedings of the association, with all the discussions relating to problems in practical agriculture, but also recommendations as to methods of research to be followed by chemists throughout the country, whether having relation to agricultural research or not. One of the most important of the works which has been undertaken, and which is now partially completed, has been in determining the standards of purity for food. The work of the Division of Chemistry in respect to food adulteration is described further on. In order, however, that a competent control of food adulteration may be exercised, it is necessary that the judicial authorities have reliable standards to which reference can be made in legal proceedings. It is evident that such standards can only be secured by the comparison of a vast amount of chemical data and an institution of the most careful research. The Association of Official Agricultural Chemists has taken up this subject in a systematic manner, and the various problems relating to the standards of pure food are placed in the hands of special committees, who have already accomplished a great part of the work which has been assigned to them. At the completion of the work it will be possible to present for the approval of Congress, and of the various legislative bodies of the country, a system of food standards, just and correct, based upon the widest knowledge and the most careful research. With the aid of these standards the enforcement of pure-food laws will be made easy and the punishment of those who violate their provisions rendered certain. The proceedings of the association and the methods of analysis and research adopted by them are found in the bulletins issued from the Division of Chemistry.

CHEMISTRY IN AGRICULTURAL REPORTS OF THE PATENT OFFICE, ETC.

NUTRITION.

The first work of agricultural chemistry was naturally to develop the principles upon which plant nutrition is based. It was soon seen, however, that animal nutrition rests upon the same general principles, and that the same methods of research, with the necessary modifications for the changed environment, are to be used in both cases. Thus early the aid of chemistry was invoked in establishing the true principles of animal feeding. But little was known of a positive nature in this matter in the early parts of the century. Toward the middle of the century, however, considerable contributions had been made by agricultural chemists to this subject. The Agricultural Reports of the Patent Office in early years contained articles on this subject. In the report for 1849 several pages are given to the discussion of the nutritive value of foods. The comparative value of the whole flour of wheat as compared with the fine flour is also given, and the contributions of Peligot, the celebrated French physiological chemist, are freely referred to. An interesting chapter is also contributed on the nutritious properties of various other articles of food, and the chemical methods which were in vogue for determining the composition of wheat flour and of ascertaining its nutritive value are set forth in some detail. The work of the Department of Agriculture in regard to the principles of nutrition has been prosecuted with more or less vigor by chemists connected with its service from the middle of the century to the present time. In the agricultural experiment stations also the principles of animal feeding have been fully developed by practical work. The general principles of animal nutrition were made available for farmers' use at an early day by the publication of Armsby's "Manual of cattle feeding," in the year 1880. Although this was essentially a translation of a foreign work, yet in its publication various improvements and additions were made by the author and translator, which rendered the book far more valuable than the original work. Among the later publications on the same subject may be mentioned the work of Professor Henry, published in 1898. In addition to this, various bulletins from the Division of Chemistry and from the Office of Experiment Stations of the Department of Agriculture have been issued from time to time on the subject of nutrition and on the composition and nutritive value of foods in general.

As the result of all these investigations the practical farmers of the country have now at their command, and in forms which they can fully understand, the great principles of animal nutrition. It is certain that the actual cost of the food required for placing an animal upon the market for meat or in preparing it for work has been very much diminished. Even if no further progress were made in the science of nutrition, the economic results which have been obtained in this line would be a sufficient justification for all the expenditure of money, time, and labor which has been incurred in the progress of agricultural chemistry up to the present moment. While it is doubtless true that many great discoveries are yet to be made in the domain of the science of nutrition, yet enough is now known to illustrate fully the circle of life beginning with the inorganic matters in the soil, in the air, and in the water, passing through the organism of the plant, and reaching the highest form of organized matter in the living animal. The investigations in nutrition have even gone further than this, and show how the elements of food, both for plants and animals, after having served their complete functions in one or the other of these organisms, or in both, are preserved intact, to be returned to the original condition of mineral substances in the soil, in the air, and in the water, to begin anew the circle of life. The present era, therefore, finds established as definite scientific principles the prescient predictions of the great Lavoisier concerning the methods of plant and animal nutrition.

DANGER OF EXPORTING PLANT FOOD.

The work done in the Division of Chemistry, as well as by agricultural chemists in other parts of the country, has called attention to the danger of unlimited exportation of food products containing large quantities of plant food. In fact, early in the history of the Department of Agriculture attention was called to this matter. In the Agricultural Report of the Patent Office for 1849 mention is made of the fact that prior to 1846 Ireland was an exporter of large quantities of cereals, sending abroad more of them than the whole of the United States. Much of the grain sent from Ireland was oats. The exhausting effect of cropping a field to oats is known to all practical farmers, and to this is attributed the fact of the subsequent failure of the crops in Ireland and the great suffering due to the famines caused thereby. An elaborate report on the subject of exporting plant food was presented by the present chief of the Division of Chemistry in his address before the American Association for the Advancement of Science in the Buffalo meeting of 1886. In this report the quantities of plant food removed by the crops from the fields of the United States annually were set forth. The value of plant food lost at that time by exportation of farm products was, by a careful computation, found to be over $33,000,000 per annum. Since that time the exportation of farm products from this country has almost doubled, so that at the close of the century it is safe to say that the value of the plant food, calculated from a manurial standpoint, lost by exportation from the United States is not far from $70,000,000 per annum.

This subject was more fully developed in an address delivered before the American Chemical Society on December 27, 1893, at the Boston meeting. While it is true, as illustrated in these addresses, that the quantities of plant food lost by exportation are less than by other causes, nevertheless the danger of exhausting the fertility of fields by the continual sale of agricultural crops is fully understood. Chemical researches in the Department of Agriculture and in other parts of the country have established this principle beyond peradventure, and have taught the farmers of the United States that one of the surest methods of retaining the fertility of their soil is to feed as much as possible of the crops produced at home. The home feeding of domesticated animals secures a large part of the value of the food in the form of manure, and this tends to diminish the rate at which otherwise the fertility of the fields would be exhausted. Chemistry has shown that there are certain products of the fields, however, which can be exported or sold with no loss in fertilizing materials. Among these may be mentioned starch, sugar, cotton, and oils and fats of every description. These bodies, contrary to the views held at the beginning of the century, are now known to have no value whatever as plant foods, and hence can be sold from the farm with impunity. It is true that no system of farming can be devised which will absolutely prevent the removal of certain quantities of plant foods in the crops; but scientific agriculture, founded upon chemical investigations, will lead farmers to that course of practical economy which will bring to a minimum the loss of fertility from this cause.

RESEARCHES ON DAIRY PRODUCTS.

The importance of the chemical composition of the dairy products was early recognized in the chemical work of the Department of Agriculture, and the Agricultural Report of the Patent Office for 1849 contains an article on the chemical properties of milk and butter. The research work of the Department on these products has been continued at intervals since that time, and important publications devoted to this subject have been issued. The Division of Chemistry, since the establishment of the Bureau of Animal Industry, has cooperated with that Bureau in the study of dairy products from a chemical and physiological point of view, and this cooperation is still continued.

IMPROVEMENT OF WORN-OUT LANDS.

Special researches have been made in the Division of Chemistry of the Department of Agriculture on the methods of improving worn-out lands. Early in the history of the Department this study was recognized as an important one, and an article is found in the Agricultural Report of the Patent Office for 1849 on the improvement of worn-out lands by the use of peas and clover. At intervals since then this subject has received the attention of chemical research, not only in the Department but in other parts of the country. A bulletin on the subject of the reclamation of worn-out lands was issued in 1894, a large part of which was contributed from the Division of Chemistry. The researches which the agricultural chemists have made, in collaboration with other scientific work of a botanical and mechanical nature, point out the way whereby lands which have been deprived of the greater part of their fertility and otherwise exhausted by culture may be restored to a high degree of fertility. In many parts of the United States are found abandoned fields and even farms, since it has been found more profitable to search for new and fertile soils than to develop and restore old and worn-out fields. At the present time, however, the area of virgin fertile soils is practically exhausted, and the attention of scientific agriculture is now directed with more energy than ever to the restoration of the fertility of soils long since abandoned. It is certain that in the near future the practical farmer, with the aid of chemical research, will effect the restoration of the greater part of the agricultural lands of the United States, which have heretofore been abandoned to briars and brush, to their natural position as fertile and profitable fields.

CHEMISTRY IN THE DEPARTMENT OF AGRICULTURE.

Perhaps there is no other method in which the researches of chemistry have been made practical for agricultural purposes in a more general way to the agriculture of the United States than through the work of the Department of Agriculture. So long as the work of the Department was conducted in the Patent Office, chemical investigations of agricultural subjects continued to be the chief scientific inquiry.

ANALYSIS OF GRAINS AND OF FLOUR AND MEAL MANUFACTURED FROM THEM FOR EXPORTATION.

The first appropriation in this country for purely scientific services in agriculture was made at the first session of the Thirtieth Congress, when $1,000 was given "for the institution of a system of analyses of different grains produced in this country and of flour manufactured here and exported abroad."

The important problems which it was sought to solve in these investigations were the effect of soil and climate upon the different varieties of grains and the effect of a sea voyage and storage upon the flour and meal manufactured from grains produced here and sent abroad.

Prof. Lewis C. Beck, of Rutgers College, New Brunswick, N. J., an experienced analytical chemist, was employed to conduct the chemical work. The Commissioner of Patents made efforts to receive samples of wheat, indian corn, and flour from the ports of the most distant countries to which they had been exported. Professor Beck's report is made an appendix to the Agricultural Report of the Patent Office for the year 1848. Professor Beck, in introducing his report, enters into an elaborate discussion of the economic relations of chemical studies to agriculture. He states that in 1847 breadstuffs worth $43,000,000 were exported from this country to Great Britain and Ireland alone. He is of the opinion that the best method of determining the real value of wheat and other flours is to examine the bread made from them, and calls attention to the fact that chemicals are used in some countries in the manufacture of bread in order to conceal the defects of the flour from which it is made.

In Belgium and the north of France it is stated that sulphate of copper has been introduced into the manufacture of bread, and that the use of alum has been practiced from a remote period. In addition to these, the alkaline carbonates, the carbonate of magnesia, chalk, pipeclay, and plaster of Paris have all been employed in the manufacture of bread from inferior or damaged flour in order to preserve its moisture or to increase its weight and whiteness. Further adulterations of bread are stated to be with potato starch and flour of leguminous plants, buckwheat, and rice, and citations are made to the literature where the methods of discovering these adulterations can be found. Professor Beck quotes largely from Boussingault's "Rural Economy," Dumas's "Traité de Chimie Appliquée aux Arts," and from Davy's "Agricultural Chemistry." The method of analysis employed by him is fully set forth, and the data obtained from the numerous analyses are given, showing the amount of water, gluten, starch, and sugars contained in the various samples. In all, thirty-three samples of flour were analyzed, collected from different parts of the country, and from distant ports to which flour from this country had been shipped.

It is thus seen that several of the most important lines of investigation which have subsequently been followed in the chemical work of the Department were marked out at this early period by Professor Beck. He introduced the first systematic work in determining the character of the cereals of the country, published methods of analysis for the guidance of other chemists engaged in similar work, and began the investigation of the great subject of food adulteration.

A similar work on indian corn was conducted by Dr. J. H. Salisbury, of Albany, N. Y., and the results of his analyses were published in the report for 1849.

ESTABLISHMENT OF DIVISION OF CHEMISTRY.

In 1862 the Department of Agriculture was organized on an independent basis. In the organic act establishing the Department it is stated that the Commissioner of Agriculture shall "employ other persons for such time as their services may be needed, including chemists, botanists, entomologists, and other persons skilled in the natural sciences pertaining to agriculture."

It is thus seen that chemistry was recognized, by its assignment in the order of mention, as of the first importance in the scientific work of promoting agriculture throughout the country. In accordance with the authority vested in him by the organic act, Isaac Newton, who was the first Commissioner of Agriculture, established the Division of Chemistry by the appointment of Dr. C. M. Wetherill, a distinguished chemist, as the first chief of Division. Dr. Wetherill was appointed Chemist on August 21, 1862, and served until some time in 1863.

Commissioner Newton, confirming the statement made by Judge Buell more than twenty years before, gave as the first of the scientific objects of the Department "analysis, by means of a chemical laboratory, of various soils, grains, fruits, plants, vegetables, and manures, and publishing the results for the guidance and benefit of agriculturists."[1] Of the work of the Chemist for the first year, the Commissioner said:

> Fortunately the Chemist to the Department was in possession of an extensive scientific library and apparatus, which he kindly placed at my disposal at the commencement of my duties as Commissioner. The season had so far advanced, however, that but few tests could be made. The Chemist has, nevertheless, analyzed some twenty-two varieties of grapes, and is at present engaged in the examination of ten or twelve varieties of wines, also sorghum from eight or ten different localities, in order to determine the relative value of sirup and its capabilities for producing sugar and molasses, as compared with sugar cane. As soon as arrangements now being made in the laboratory are completed, the Chemist will enter into the analysis of the various grasses and grains of the United States, in order to learn which will produce the greatest amount of fat, flesh, muscle, and bone; also of soils, manures, and the constituents of plants, with especial reference to restoring fertility to exhausted farms.

REPORTS OF THE CHEMISTS.

On January 1, 1863, the first report of the Chemist of the Department of Agriculture was submitted for publication. This report is interesting as the first one on a scientific subject ever made to the Department by a person employed exclusively for the conduct of scientific work. The Chemist's report covers the analysis of grape juices, of sorghum and imphee, the examination of various sugars and sirups, the analysis of beets, and an article on the chemistry of sugar manufacture in general. Thus, at the very outset of the special relations of chemical science to the Department of Agriculture, some of the most important lines of investigation which have since been followed were established. Chief among these may be mentioned the study of the wine-making industry, both from the fermentative and chemical points of view, and the beginning of that study in the chemistry and technics of sugar manufacture, which has since done so much to establish an indigenous sugar industry in the United States.

The Annual Report of the Commissioner for 1863 contains no report from the Chemist of the Department.

The report of the Chemist for 1864 (Mr. Henry Erni[2]) relates to organic or vinous fermentation, acetic fermentation, butyric-acid fermentation, theories of the origin of mold, or fungi, methods of detecting the artificial coloring matters in wines, the analysis of wines, and the analysis of soils and guanos.

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[1] Report of the Commissioner of Agriculture, 1862, p. 20, object 5.

[2] Appointed probably July 1, 1864.

The report for 1865 was devoted to the analysis of soils, sugar beets, sorghum and imphee, wines, and miscellaneous work of various descriptions.

In 1866 Dr. Thomas Antisell[1] was appointed Chemist of the Department. His first report was devoted to the analysis of soils and manures, agricultural products, and mineral and metallurgical analyses. During this year also the cooperative work between the Division of Chemistry and other Departments was begun. Dr. Antisell says, on page 45 of the Annual Report: "Besides the foregoing, the laboratory has been engaged with analyses for other Departments of the public service."

Dr. Antisell, in his report for 1867, enters into an elaborate discussion of the analysis of sugar beets and of the sugar-beet industry, thus having laid the foundation for the extensive developments in the investigations along this line, which have been carried on by the Division of Chemistry for the past thirty years. In order to increase the efficiency of the work of the Division, Dr. Antisell suggested that the scope of its work should be enlarged so as to embrace the relations of geology to agriculture and to include the study of metallurgy. He suggested that geology had intimate relations to agriculture, and advised the establishment of a geological and mineralogical laboratory and museum to illustrate the economical relations of geology to the agriculture of the United States. He says: "Whatever relations of soils to their parent rocks exist would thus be brought out in a prominent and systematic manner." It will be observed from this reference that the first official recommendation for the establishment of a geological survey emanated from the Division of Chemistry of the Department of Agriculture, as well as the suggestion of the study of meteorology and other matters connected directly with agricultural crops.

In 1868 the chemical laboratory was removed from the Patent Office to the building of the Department of Agriculture, which had just been completed. The report of the Chemist for that year contains a reference to the newly discovered phosphatic deposits of South Carolina, with remarks upon their value for agricultural purposes.

The report for 1869 contains an interesting article on the analysis of soils. The Chemist also urges the establishment of an experimental garden, where the problems involved in chemical research could be studied actually in the field. This recommendation was a reiteration of one previously made by him in the same direction. The importance of practical experimental stations in connection with chemical research is thus early in the history of the work of the Division properly recognized.

The report of the Chemist for 1870 contains an interesting article on the alkaline soils of the West, giving a complete study of their

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[1] Appointed probably July, 1866.

physical and chemical properties, especially an account of the determination of the soluble matter in the surface. The first work which had been undertaken on the composition of meat extracts is also discussed in the report, as well as the foods used by the Indians.

The work for 1871 is described by the Commissioner in his report for that year as being memorable on account of the beginning of two extensive investigations. One of these was the analysis of several hundred specimens of cereals carefully selected from the entire production of the country. The other was the examination of the leaf, stem, and fruit of the grapevine during every week of its growth. The Commissioner says: "By this work it is expected that new analogies in animal and vegetable physiology will be established and information gained which bears directly upon the diseases of the vine."

From the earliest establishment of chemical researches in the Department, a large part of the time of the Chemist and his assistants had been taken up with analyses not at all relating to agriculture. Chief among these were the assay of gold and silver ores and the study of samples for commercial purposes for private individuals and corporations. This perversion of the proper functions of the Division of Chemistry had been so pronounced as to warrant the Commissioner to say in the report for 1871: "To enable the Chemist to devote himself to those important subjects in agricultural science which await and demand chemical research, I am strongly of the opinion that the public privilege should be restricted to the employment of the laboratory for such purposes only as relate to agriculture."

In July, 1871, Dr. Antisell resigned the position of Chemist, and on January 11, 1872, Dr. R. T. Brown was appointed to the position. The report of the Chemist for that year emphasized the importance of sodium nitrate as a manure, and the value of the deposits in Peru, Chile, and Bolivia for agricultural purposes is mentioned. Attention is called to the fact that the soils of the blue-grass region of Kentucky renew their stock of phosphatic materials by the decomposition of the limestone rocks, and this observation has in later years been confirmed by the researches of the agricultural experiment station of Kentucky, which show that these soils are never deficient in phosphates, but only in potash and nitrogen. The importance of bone and natural phosphates for fertilizing purposes is more fully brought out in this report than in any previous contribution from the Department, and large numbers of analyses of commercial fertilizers are given.

In 1872 the report was devoted largely to the analysis of commercial fertilizers and sugar beets. An important contribution is also found in this report on the utilization of the wastes of cities and towns for agricultural purposes, a subject which has since received very careful investigation in the Division of Chemistry.

In 1873 Dr. Brown resigned and was succeeded by Dr. William McMurtrie, who held the position until January 2, 1878.

In the first report of Dr. McMurtrie attention is again called to the fact that the Department has been very much troubled with applications for analyses of minerals, ores, commercial products, etc., which have little or no bearing upon agriculture or agricultural chemistry. The work during the first year of Dr. McMurtrie's incumbency was largely devoted to the analysis of wines, fertilizers, and soils. An interesting résumé of the knowledge at that time relating to humus is given, with references to the work of Grandeau on that subject. Another interesting article in this report is a contribution on the approximate composition of cereals, indian corn being the one selected for study. The first investigation relating to tanning materials was also reported at this time.

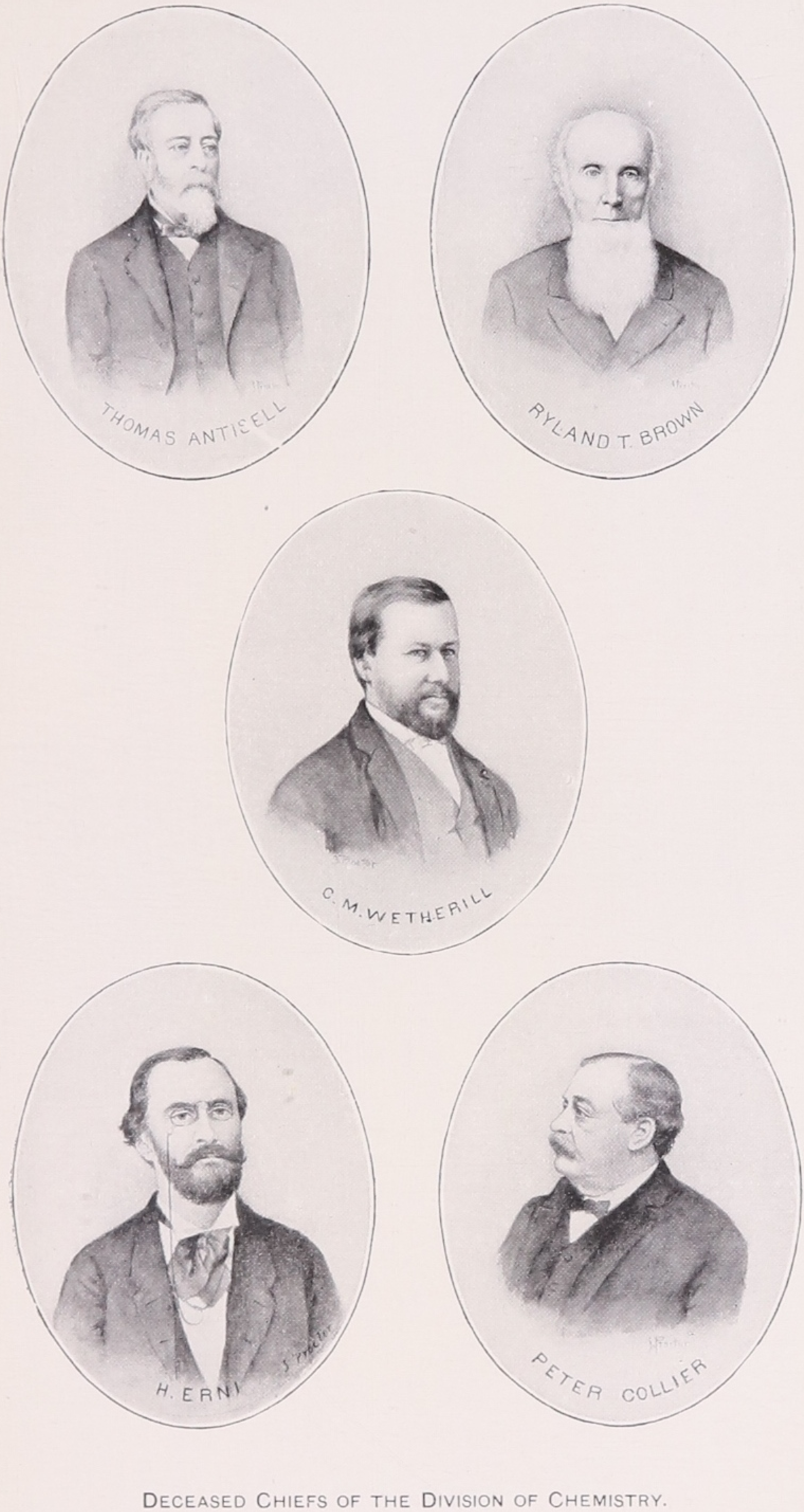
The Chemist's report for 1874 includes a report of an investigation of the fodder plants of the South and a study of insecticides, especially Paris green, in regard to their use in agriculture. Reference is also made to the work of Dr. Goessmann, of the Massachusetts Agricultural College, on the culture of the sugar beet. This was the beginning of Dr. McMurtrie's investigations of the sugar-beet industry, which he afterwards carried forward with such success and advantage to American agriculture.

In the work of 1875 the first studies were commenced in chemical processes affecting agriculture by the actual growth of plants. A series of valuable experiments was conducted in the application of insecticides to growing plants. The effects of these insecticides were carefully noted and photographs representing the plants treated were secured and published. Similar experiments were made to show the effects of illuminating gas upon vegetation. This was the beginning of the realization of the recommendations made by Dr. Antisell for the practical investigation of agricultural chemical problems upon the plant itself.

The report for 1876 refers to the part taken by the Division in the Centennial Exposition which was held during that year at Philadelphia.

The work for 1877 is summarized in the report of the Chemist under nine different heads, namely: (1) Analysis of lime marls; (2) examination of soils; (3) analysis of bat guano; (4) analysis of sugar from Early Amber sorghum cane; (5) estimation of the amount of sugar in various beets sent to the Department; (6) the examination and report of an experiment in beet culture made on Batsto farm, Atlantic County, N. J.; (7) experiments to determine the presence or absence of the so-called peptone-forming ferment in the roots of plants; (8) investigation of American sumac; (9) investigation of the physical and chemical causes tending to the production of mildew and rot. The latter investigation is interesting from the fact that it indicates that the first beginnings of studies of this kind were established in the Division of Chemistry.

At the beginning of 1878 Dr. McMurtrie resigned to accept the



DECEASED CHIEFS OF THE DIVISION OF CHEMISTRY.

position of representative of the Department at the international exposition to be held at Paris during the year, and January 22, 1878, Dr. Peter Collier was appointed Chemist in his stead.

The first report of Dr. Collier covers the beginning of the work conducted by him on the production of sugar from indian-corn stalks and from sorghum. While, however, during this first year only 8 samples of these sugar-producing plants were examined, 57 sugar beets were analyzed. A joint report of the Botanist and Chemist on grasses and forage plants, issued January, 1884, is interesting as showing, in an ideal way, the methods in which the different scientific Divisions of the Department may collaborate in advancing the interests of agriculture. Dr. Collier held the office of Chemist until April 9, 1883. During this time a large part of the activity of the Division of Chemistry was devoted to the study of sorghum as a sugar-producing plant, and the most extensive series of analyses ever instituted up to that time for agricultural purposes was conducted under his direction.

The reports prepared by Dr. Collier on this matter and appearing in the several annual reports deal with every phase of the subject, chemical, agricultural, and technical. The high price of sugar at this time excited the interest of investors in the subject of the practical manufacture of sugar from sorghum, and a large amount of capital was placed in this business. Unfortunately for the sorghum industry, the rapid development of the beet-sugar industry in Europe brought into competition with sorghum a sugar-producing plant which, under the impetus of careful chemical study and technology, rapidly produced a surplus of sugar in the markets of the world, causing an unprecedented fall in price. The difficulties attending the manufacture of sugar from sorghum, due to the chemical composition of the plant, were not solved with sufficient rapidity to enable sorghum to remain as a competitor for supplying the sugar markets of the world. As a result of this combination of economic, chemical, and technical causes, the production of sugar from sorghum never became profitable. While, as stated, the study of the sugar problem was the main work of the Division of Chemistry during the incumbency of Dr. Collier, other matters, relating to agricultural industries were not neglected. The study of soils and fertilizers was continued without intermission, and the foundation was laid for the systematic study of cereals, which afterwards became so important a part of the work of the Division.

The portraits of the deceased chiefs of the Division of Chemistry are given in Pl. V.

LINES OF WORK IN THE DIVISION OF CHEMISTRY SINCE 1883.

Since April, 1883, the work of the Division of Chemistry in its relation to the progress of agriculture has been directed chiefly along the following lines:

Study of sorghum.

The study of sorghum as a sugar-producing crop was continued with the special object of overcoming, if possible, the difficulties which had stood in the way of a successful industry. At first the work was more of a chemical and technical nature, looking to the establishment of methods to secure more economical working and larger yields. To this end, the diffusion process of extracting the sugar from the canes, which had been so successfully used with beets in Europe, was applied to sorghum with such modifications as the different nature of the material required. An increase in the amount of sugar extracted from the canes was easily obtained, but the greatest difficulty in the way of successful sugar making still remained, namely, the chemical composition of the extracted juices. It was found that the juices extracted from sorghum canes contain large quantities of starch, gummy matters, and uncrystallizable sugars. These existed in such large proportions as to render the separation of the sucrose in large quantities practically impossible. Various chemical methods of removing these impurities were devised and applied. Among them, the two which promised most success were the process of saturation with lime, or carbonatation, as practiced with beet juices, and the removal of the starchy and gummy matters by precipitation with alcohol. The former method, after a thorough trial, was abandoned as impracticable. The latter method resulted in a complete success, yielding with canes of average composition 200 pounds of sugar per ton. The fiscal regulations covering the production and use of alcohol in this country, however, were of such a nature as to render the use of this reagent impracticable from an economical point of view without some change in the excise laws of the country.

Meanwhile other investigations were carried on with great success; among them the process of developing a variety or varieties of sorghum in which the objectionable qualities would be reduced to a minimum and the percentage of sugar raised to a maximum. This desirable end was accomplished by a series of culture experiments in cooperation with Mr. A. A. Denton extending over eight years, in which, by a process of selection, both from the point of chemical composition and from physical qualities, several varieties of sorghum were developed, which were far superior to any which had before been known. It was established by the researches of the Division that fields of sorghum could be grown having an average sugar content of 14 per cent and with a much higher purity than characterized the parent canes from which the varieties were derived.

In spite of all the progress made, however, it was found that the increasing competition of sugar derived from the sugar beet had decreased the price of sugar in the world's markets, until it would not be profitable to manufacture sugar from sorghum, even under the more favorable circumstances which obtained. But the final results of these investigations were not without their practical value, as the utility of sorghum as a source of table sirups and as a cattle food was fully developed and established. It was also shown that in the semiarid regions of the country, where the practice of irrigation was not possible, there is no crop which is so certain to bring a remunerative yield as sorghum when cultivated in the proper manner.

The final result of the work conducted by the Division over a period of more than twenty years on sorghum as a field crop has established its status as one of the most remunerative plants when cultivated in certain areas of the country. In fact there is scarcely any part of the United States where sorghum is not cultivated, and even in Minnesota the finest table sirups which are found upon the market in that region are made from one of the early varieties of sorghum cane which grows to maturity in the short summer seasons of that State.

Study of cereals.

Another line of investigation which has been carried on extensively during the past seventeen years has been a study of the composition of the cereals of the United States. This work, it is true, as has been stated, is only a continuation of the very first scientific work authorized by the Government when the Department was still a section of the Patent Office. The opportunities, however, for the use of more accurate means of analysis and to secure samples grown under different conditions, from more widely separated areas, have made the continuation of this study one of the most profitable for the advancement of agriculture. The bulletins which have been issued on this subject embody the results of many thousands of analyses, and show with greater fullness and accuracy than any other publications which have been issued the variation of cereal products under different conditions of soil and climate. The successful work of improving a plant by selection and taking advantage of natural variations, as illustrated in the case of sorghum, has now been applied to the study of cereals. The causes which produce variations are under investigation, and also the methods for improving the composition of cereals with reference to certain of their more valuable constituent parts. For instance, the percentage of gluten in wheat is of the utmost importance to the bread maker, since it is this body which gives to wheat flour the physical characteristics that render it more valuable than that from other cereals for bread-making purposes. Under the varying conditions of soil and climate in this country it is found that the content of gluten in wheat changes. The utmost practical advantage, therefore, will come to the wheat grower from a practical study of this cause and suggestions of the best methods of preserving or increasing the content of gluten in wheat.

The broad principle has been established that, other things being equal, wheats from a high northern latitude contain more gluten than those grown farther south and the wheats that are sown in the spring a larger quantity of gluten than those which are planted in the autumn. It is believed, however, that a careful chemical study of this subject in connection with the proper study of meteorological conditions will enable wheat growers to largely increase the content of gluten in the autumn-grown and southern wheats.

Study of food adulteration.

The practice of adulterating human foods, which has been so largely prevalent in all parts of the world, has proved of incalculable injury to honest agriculture. The value of scientific farming in its ultimate measure is determined by the benefit which accrues therefrom. If the returns from scientific farming prove to be less than those from unscientific methods, the latter will certainly prevail. The markets for farm products must therefore be preserved with as much care as the fertility of the fields. The sole object of food adulteration is to enable the unscrupulous manufacturer or dealer to sell an inferior article at the price of a superior. Food adulteration, therefore, which totally changes the aspect of the food of an inferior kind so that it does not at all resemble the superior kind would defeat its own purpose. Every pound of adulterated food which is sold upon the market at the price of the genuine article or at a price approximating thereto is a positive injury to agriculture, since it excludes from the market an equal quantity of farm products of a genuine character. Thus, the practice of food adulteration directly diminishes the profits of the honest farmer and dealer.

Much of the activity of the Division of Chemistry during the past seventeen years has been directed to a study of the methods and character of food adulteration with a view to devising proper legal restrictions for its prevention. To this end a large part of the scientific corps of the Division has been assigned to a systematic study of the adulteration of foods, and the results of these studies have been published in numerous bulletins relating to that subject. The object of these studies is to finally cover the whole range of food production, and this has already been largely accomplished.

As an illustration of the way in which adulterated foods may injure the farmer's profession may be cited the sale of oleomargarine for butter and glucose for honey. The food value of oleomargarine and of glucose is not denied. They are, however, very much cheaper products than butter and honey. These adulterated foods, unfortunately, are often not offered for sale under their own names, except by legal compulsion, but are placed upon the market under the names of the genuine articles which they are manufactured to imitate. Buyers, therefore, pay, as a rule, prices which would be asked for the pure articles. The market for the pure articles is diminished just to the extent to which these other substances are sold, and in this way positive injury to great agricultural interests is done. The chemists of many of the agricultural experiment stations throughout the country have collaborated with the Division of Chemistry in these studies, so that the whole subject of food adulteration is pretty thoroughly understood and its extent acknowledged. Many of the legislatures of the States have already enacted restrictive measures regulating the sale of adulterated foods, and bills have been before the Congress of the United States having the same object in view. The work in which the Division of Chemistry was a pioneer has commended itself to the people at large, and through the press and before farmers' institutes full descriptions of the methods and character of adulteration have been disseminated among the people. Public opinion has been so aroused on this subject as to demand of the National Legislature the enactment of laws regulating commerce in adulterated foods in the Territories of the United States and between the several States thereof. The work of the Division has therefore already secured great benefits to agriculture in the way of preserving an honest market for the products of the farm, and made it possible for these benefits to be greatly increased by favorable national legislation on the subject.

Comparative studies of soils.

For the past seventeen years the Division of Chemistry has continued its researches in the study of the soils of the United States. Before the organization of the Association of Official Agricultural Chemists, and for the benefit of agricultural chemists throughout the country, a bulletin was prepared giving the results of soil studies and a summary of the best methods known at the time for conducting them. In order to study comparatively typical soils special authorization was obtained from Congress for the establishment of a vegetation house in which soils from different parts of the country and even from foreign countries could be studied under similar conditions in respect of their powers of producing organic matter and in their relations to nitrifying organisms. In no other way can the relations of different soils from the point of view of their chemical and physical composition in producing crops be so definitely determined. A knowledge of the soil is the fundamental structure on which agricultural chemistry is built. While in all parts of the world numerous experiments have been carried on to determine the relative value of fertilizing principles on plant growth, it is believed that the comparative determination of native soil fertility under standard meteorological conditions has first been studied in this Division. The great problem of human nutrition is to find its only solution in the maintenance or increase of soil fertility, and hence every study of this kind which tends to give additional knowledge regarding the cause of fertility and the means whereby it can be maintained, is of the highest economic importance. The complete triumph of agricultural chemistry will be realized when with increased crops shall be found increased soil fertility.

The system of agriculture which has so largely prevailed in this country of exhausting the fertility of one field and then moving the farm to another has come to an end. Scientific agriculture now retraces its steps and restores the fertility of the abandoned fields while it prevents the exhaustion of those which are still productive. Agricultural chemistry in its fullest development will only ask of nature to furnish meteorological conditions and a place on which to plant the crops. Even these will be modified and changed to suit the demands of the agriculture of the future, for it is certain that by the proper manipulation of the soil and the addition of proper chemical fertilizers the capacity for retaining moisture for use in seasons of drought or for disposition of excessive moisture in seasons of rains will be greatly increased. With a wise disposition of the water at his command, the scientific farmer of the future will cultivate millions of acres which are now regarded as hopelessly arid, and recover from the excess of water other large areas now abandoned to swamps and marshes. In these scientific studies of soil composition and soil possibilities with relation to the composition of plants and to increased fertility will be found in the future, as has been the case in the past, some of the most notable triumphs of agricultural chemistry.

In connection with these soil studies, there has also been made a systematic study of the nitrifying organisms through whose agency organic and atmospheric nitrogen become available for plant food. A practically new system of soil analysis has been inaugurated by which it is possible to determine both the number and activity of the nitrifying organisms contained in a sample of soil. These researches are of the greatest practical benefit in agriculture, since they show how the number and activity of nitrifying organisms can be increased, and thus the availability of the nitrogenous food of plants be enhanced. An outline of the relations of these studies to practical agriculture has been prepared for this paper by the first assistant of the Division of Chemistry, Mr. E. E. Ewell.

RELATION OF MICROORGANISMS TO NITROGEN NUTRITION OF CULTIVATED PLANTS.

EARLY STUDIES OF MICROORGANISMS AND NITROGENOUS PLANT FOOD.

The development of the prevailing opinions relative to the rôle of the microorganisms in the preparation of the nitrogenous food of our cultivated plants is a long story. Indeed, its beginning may be traced back to the closing years of the eighteenth century (1770 to 1800), during which period the labors of Black, Scheele, Priestley, Lavoisier, Cavendish, Watt, Ingenhousz, Senebier, and Woodhouse established the chemical nature of the constituent gases of the atmosphere—nitrogen, oxygen, carbon dioxid, and water vapor—and began the study of the relation of these substances to vegetable growth. Early in the present century De Saussure materially advanced the knowledge of the processes by which the carbon dioxid and the water of the atmosphere and of the soil are converted into vegetable tissue, and expressed the opinion that the nitrogen therein contained was obtained from the compounds of that element found in the soil and in the air; but the relation of atmospheric nitrogen to vegetation remained obscure until within two decades of the century's close.

Boussingault devoted a considerable part of twenty years (1837–1858) to the study of this question. His experiments seemed to show conclusively that plants are unable to use the free, uncombined nitrogen of the air for the construction of the nitrogenous bodies which form parts of their tissues, and that their nitrogenous food is exclusively drawn from nitrogen compounds contained in the soil.

The experiments of Ville (1849–1854) led to precisely the opposite conclusion. In 1854, appreciating the importance of the subject, the Academy of Sciences of France appointed a commission, consisting of Dumas, Regnault, Payen, Decaisne, Peligot, and Chevreul, to observe and report upon a repetition of these experiments to be conducted by Ville, with the assistance of Cloez, in the Muséum d'Histoire Naturelle. In 1855 Chevreul reported on behalf of the commission "that the experiment made at the Muséum d'Histoire Naturelle by M. Ville is consistent with the conclusions which he has drawn from his previous labors."

Messrs. Lawes and Gilbert, at their now famous experimental farm at Rothamsted, England, have devoted much time to this question since 1857. Their earlier experiments (1857–1860) were negative for both leguminous and nonleguminous plants, thus contradicting the results of Ville and confirming those of Boussingault.

Two of Boussingault's experiments, made 1858–59, seemed to indicate that free nitrogen had been brought into combination either by some lupine plants or by the rich garden soil in which they were growing. He did not accept these results as evidence of the assimilation of nitrogen by plants, however, as is indicated by the following from his letter to Gilbert, dated May 19, 1876:

> As for the absorption of the gaseous nitrogen of the air by arable soil, I know of not one single irreproachable observation that establishes it. Not only does the soil not absorb gaseous nitrogen, but it emits it, as you and Mr. Lawes have observed, as Reiset has found in the case of manure, and as Schloesing and I have noted in our researches on nitrification. If there is a perfectly demonstrated fact in physiology, it is that of the nonassimilation of free nitrogen by vegetation, and I may add by the lower plants, such as the mycoderms and fungi.

Many other investigators devoted much time to this question between the years 1850 and 1886: Cloez and Gratiolet, 1850–1855; Méne, 1851; Petzholdt, 1852–53; Wolff, 1853–1886; Hasting, 1855; de Luca, 1856; Dehérain, 1875–1885; Berthelot, 1876–1886; Atwater, 1883–84; Dietzel, 1884; Joulie, 1885; Frank, 1886.

This long series of experiments, covering more than half a century of time, were contradictory, one of another, erroneous in conception in some cases, and erroneous in manipulation in others, while the conclusions drawn from them were correspondingly inaccurate and incomplete. The most fruitful source of wrong conclusions was, however, to be found in the fact that in the zeal of many of the workers to deprive their experimental soils of compounds of nitrogen they so treated them as to destroy what we now know to be the potent factor in the assimilation of free nitrogen by plants—the microorganisms which form the nodules upon the roots of leguminous plants and thereby enable the plants of that order to indirectly draw upon the atmospheric store of uncombined nitrogen. Attention had frequently been drawn to these peculiar nodular structures on the roots of clover, lupines, beans, etc., notably, by Lachmann in 1858, by Berkeley in 1863, and by Rautenberg and Kuehn in 1864. Indeed, it was suggested by some of these writers that possibly the nodules were connected in some way with the taking in of nitrogen by the plants. It came to be a well-established fact that there was a something that distinguished the manner of the nitrogen nutrition of leguminous plants from that of other plants. They were found to contain more nitrogen than it seemed possible for them to obtain from the combined nitrogen of the soil and the atmosphere in which they grew.

WORK OF BACTERIA IN THE SOIL IN SUPPLYING NITROGENOUS FOOD FOR LEGUMINOUS PLANTS.

At the Berlin meeting of the agricultural section of the Naturforscher-Versammlung, September, 1886, the late Professor Hellriegel read a paper disclosing results which have revolutionized our ideas relative to the nitrogen nutrition of plants, and which show the mistakes and the blindly groping nature of the experiments enumerated above. This paper throws a flood of light upon the path to be followed by practical agriculturists in the future. In short, Professor Hellriegel proved by evidence which has been accepted by the entire scientific world that the root nodules of leguminous plants are caused and inhabited by a species of bacteria; that these bacteria, by their symbiosis, enable the plants to indirectly feed upon the practically unlimited and costless store of free nitrogen, which forms eight-tenths of the earth's atmosphere. True, clover and other leguminous plants had previously been valued as soil renovators, but we are now able to use them with an understanding and a confidence hitherto impossible; with the hope that by their use as green manure, as food for farm animals, and as a source of merchantable produce, we may maintain the fertility of our fields, in so far as the element nitrogen is concerned, without the costly use of artificial nitrogenous manure, the nitrogen compounds of which will thereby be preserved for other industrial needs.

There is still some investigation needed to determine the most certain and economical methods of insuring an abundant supply of the nodule bacteria in soils on which leguminous crops are to be grown. Nobbe and Hiltner have secured patents for the manufacture and the use of pure cultures of several varieties of nodule organisms. These cultures are prepared on a commercial scale in Germany and placed on the market under the name of "Nitragin, a germ fertilizer for leguminous crops." The value of these preparations has been investigated by the experiment stations of Europe and of this country, but the results thus far obtained are conflicting.

WORK OF BACTERIA IN SUPPLYING NITROGENOUS FOOD FOR PLANTS IN GENERAL.

We have to this point only mentioned the microorganisms that participate in one method of nutrition of the leguminous plants. We have yet to consider those microorganisms which are active in the preparation of the nitrogen compounds on which plants in general feed, including leguminous plants growing without the assistance of the nodule bacteria. It now appears well established that combined nitrogen, chiefly in the form of nitrates, is practically the sole nitrogenous food of agricultural plants in general.

It is to be noted, however, that a method for enabling nonnitrogenous plants to draw their supply of nitrogen from the atmosphere has been brought to the attention of agricultural scientists during the last decade. The cultures of the organism for which this property is claimed are manufactured in Germany and sold under the name of "Alinit." The experiments which have hitherto been made with "Alinit" as an agent for soil inoculation have not confirmed the claims of Caron, the German agriculturist, who discovered the *Bacillus ellenbachensis* α, the organism contained in "Alinit," and the interesting properties with which he credits it. There is, however, some experimental evidence, obtained in the laboratory, which is more favorable to it.

Since we must furnish our agricultural plants in general with an abundant supply of nitrogenous plant food, chiefly in the form of nitrates, there is no more important question in agricultural science than that of the manner in which this is to be done with certainty and with the greatest economy. Although the judicious introduction of leguminous plants into our systems of crop rotation and stock feeding may make the farmer independent of the dealer in commercial nitrogenous manures, it is still necessary to study with earnestness the methods by which the supply of crude nitrogenous compounds contained in barnyard manures and in crop residues are to be transformed into nitrates speedily and with the least possible loss.

It has long been a common experience that straw, manures, etc., when incorporated with arable soil, are found to have disappeared after some weeks or months, and that crops planted on the soil so treated grow more luxuriantly than upon adjoining unmanured land. The agencies by which organic matter is thus destroyed and changed into plant food were not at all understood at the beginning of the present century. Some of the most important facts remained unknown until the eighth decade, and even now there are many points requiring further elucidation.

The first six decades of the century were spent in experiments and disputations which served to determine the relations of microorganisms to the phenomena of fermentation and putrefaction, and to settle in the negative the much controverted question in regard to the spontaneous generation of those organisms. In this connection, we must recall the names of several persons prominent in the controversy, or in the events which led up to it: The Hollander Antoon van Leuwenhoek, "the father of micrography," who lived from 1632 to 1723, was the first to observe minute organisms in fermenting and putrescent liquids by means of the microscope; Needham, 1754, and Spallanzani, about 1760–1770, who were champions pro and con, respectively, of the theory of spontaneous generation; Schultze, 1836, who first asserted that the phenomena of putrefaction and fermentation are induced by the microorganisms ever present in the air and not by spontaneously created organisms; Schwann, 1839, founder of the science of antiseptics, who was another opponent of the theory of spontaneous generation; Liebig, who asserted in 1839 and for many years after that fermentation and putrefaction are not biological phenomena; Schröder and Dusch, 1853, who were inventors of the use of cotton wool for freeing a stream of air from microorganisms; Pasteur, who, beginning the study of the question in response to a prize offered in 1860 by the Paris Academy of Science, demonstrated that any substance whatever may be freed from the germs of putrefaction by a suitably prolonged heating at a sufficiently high temperature, and that the substances so sterilized will maintain that condition indefinitely if the access of organisms from the air is prevented.

This forms the starting point from which has been developed, by a host of workers, our knowledge of the organisms of putrefaction and decay, the changes which they work in the media in which they grow, and the conditions which favor or hinder their growth. It was early discovered that a great number of species of organisms is engaged in the destruction of organic matter in soils and other substances, and that the final products of the process are carbon dioxid, water, and ammonia, with some free nitrogen, and hydrogen in some cases.

It was a well-known fact, however, that ammonia does not accumulate in arable soils in any such quantities as do nitrates, especially under conditions highly favorable for the phenomenon of nitrification, as in the artificial and natural nitrate beds, which were under observation in various parts of the world.

The next point of contention was very naturally the nature of the process by which the nitrogen of ammonia is converted into the form of nitrates under natural conditions. Although Müller, in 1873, and Pasteur, as early as 1862, had suggested the possibility of its being a biological phenomenon or species of fermentation, the change was generally regarded as a purely chemical one, probably wrought by the highly condensed oxygen supposed to exist in the interstices of the soil and of other porous substances. This doctrine was overthrown by the experiments of Schloesing and Müntz (1876), which showed that nitrification is interrupted by the action of antiseptics (chloroform), and that the process can be started again by inoculating the medium with a small amount of fresh soil. These experiments were soon repeated and extended by the discoverers and by Warington, Soyka, and others. An additional proof of the fermentative nature of the process of nitrification was found in the fact that it was stopped by heat when applied in the manner in which it is usually employed for sterilization. During the next thirteen years (1878–1890) many workers took up the study of the nitrifying organisms, and much valuable knowledge relative to their properties was obtained, but the numerous attempts to satisfactorily isolate them and study them apart from the host of other soil organisms were fruitless. Again, an unknown factor rendered futile the efforts of some of our best experimenters, as had been the case in the investigation of the question of the fixation of free nitrogen by agricultural plants, mentioned above. The valuable method of gelatin-plate cultivation invented by Koch for the isolation of bacteria, was found to be inapplicable. Indeed, numerous failures led Frank, as late as 1887, to assert that there could be no organism of nitrification, since no organism separated from the soil was found to possess that property, in spite of the fact that numbers of experimenters had transferred the nitrifying agent from culture to culture, in liquid media, by the usual method of inoculation. It gradually became apparent that the organic matter habitually used in the media employed in plate cultivations was unfavorable to the growth of the nitrifying organisms. Indeed, by repeatedly reducing the proportion of organic matter used in the preparation of liquid media, in which nitrification proceeded satisfactorily, a medium was finally tried which contained no added carbon other than that of the alkaline or earthy carbonates which had been found necessary to neutralize the acid formed by the process, and of which an excess had been found to be detrimental. In this medium the process proceeded with the vigor normal for the liquid media hitherto found most favorable.

Here then was the key to the situation. The organisms of nitrification do not thrive in the presence of an excess of organic matter. In 1890 a new investigator entered the field, a young Russian named Winogradsky. His first triumph was in a satisfactory isolation of the nitric organisms by means of culture plates composed of gelatinized silica, impregnated with nutritive salts and carbonates, but made without any added organic matter whatever. His work upon the subject was temporarily interrupted, but it is now in progress with one or more collaborators.

In addition to the above, there must be mentioned to complete this very brief sketch of the history of the development of the knowledge of the phenomenon of nitrification and of the organisms to which it is due, the work of Warington, Frankland, Jordan and Richards, Godlewski, Burri, Stutzer, Hartleb, Lawes and Gilbert, Dehérain, and others. The results of their joint labors teach us that in order that nitrification may be active in our fields the soil must be well aerated by stirring or by improving its mechanical condition; that a proper degree of moisture must be maintained, and that excessive acidity must be prevented or destroyed by liming. Indeed, this fact explains much of the beneficial action that is known to attend the application of lime to arable land, and strongly argues in favor of a judicious extension of such use. The work of the Division of Chemistry has shown that the nitrifying organisms from soils from all parts of the country are uniformly highly susceptible to the inimical action of an excess of acids in the medium in which they grow.

INJURIOUS SOIL BACTERIA.

We have still to consider a class of soil organisms which are able under certain conditions to destroy a considerable part of the beneficial work of the organisms mentioned above by decomposing the nitrates contained in the soil and returning the nitrogen in them to the atmosphere in the form of free nitrogen. These organisms are normally present in soils and manures and upon crop residues, but only seem to exert their destructive powers in the presence of such an excess of organic matter and under such definite conditions of aeration as seldom obtain in well-tilled soil of good quality and location. Some alarm was occasioned a few years ago by the announcement by German investigators that all stable manures should be sterilized before applying them to the soil, in order to destroy these denitrifying organisms, but this was not supported by subsequent investigation, nor is it generally regarded as good counsel, as the decomposition of the manure is delayed by such a practice.

CARE OF MICROORGANISMS AS NECESSARY AS CARE OF CROPS.

From the above statements the conclusion follows that the farmer must care for the microscopic organisms growing in his soil, manure pits, and compost heaps, as well as give unceasing attention to the crops which make their appeals directly to his unaided eye. It may be well to add, however, that the best interpretation of the experience hitherto gained is that the farmer should seek to make his soils a highly favorable home for the organisms he wishes to thrive there, rather than attempt to transplant them by "soil inoculation." The rapidity with which most organisms multiply and their extremely wide distribution show that they are sure to follow their favorite food and other conditions of growth sooner or later. It may of course be true in many cases that time will be saved by inoculating the soil or seed with the organism desired.

The same principle should govern endeavors to eliminate organisms which are found to be unfavorable.

AGRICULTURAL CHEMICAL TECHNOLOGY.

Chemistry has done much to promote the progress of agriculture in the line of chemical technology. Good markets for farm products, as has already been stated, are essential to progress and prosperity. Many of the raw materials produced upon the farm enter at once into manufacture, and their value on the market largely depends upon the demand for manufacturing purposes. The principal agricultural chemical industries are starch and glucose manufacture, sugar manufacture, wine making, brewing, distilling, tanning, and fertilizer manufacture. In all these industries chemistry plays a leading part.

STARCH MANUFACTURE.

In the making of starch, chemical science has brought the utilization of the by-products to such perfection that the value of these products alone more than pays the whole expense of manufacture. This fact enables the producers to put the starch upon the market at a price far below what would be possible if chemistry had not come to the aid of the industry. Thus, a vastly greater demand for the raw materials of which starch is made is secured. In Europe potatoes are the principal source of starch, while in the United States indian corn is practically the sole material of economic importance used for this purpose. It is true that in Maine there is a large industry devoted to the manufacture of starch from potatoes, and a few small factories are found in other parts of the country, notably Michigan. The total quantity of starch, however, made from potatoes is extremely small when compared with the product from indian corn. In the manufacture of starch from indian corn chemical problems of the greatest importance are involved. The presence of nitrogenous matter in starch is undesirable, and the separation of the starch in the indian corn from the nitrogenous materials is of the utmost consequence to successful manufacture. By chemical processes, joined with mechanical ingenuity, this separation is now effected in such a way as to leave the nitrogenous matters in a state suitable for animal food. Thus, while, on the one hand, the starch of the indian corn is obtained in a practically pure state, on the other, the waste products are recovered in the form of cattle food of high nutritive value. Again, the germs of indian corn are composed chiefly of oil and protein matter. These are also separated in the process of manufacture, the oil is expressed, and the residue forms a food extremely rich in protein, and valuable both as a cattle food and as a fertilizer. The oil itself, by chemical processes, is prepared for various purposes, among others for the manufacture of a material resembling rubber. All these results have been accomplished by the application in a practical way of the principles derived from chemical investigations.

GLUCOSE MANUFACTURE.

The manufacture of glucose from starch is a chemical process pure and simple. In chemical studies it was early discovered that when starch was submitted to the action of certain ferments and acids it was converted into sugar. This is the principle upon which the manufacture of glucose rests. Formerly sulphuric acid was chiefly employed in producing this hydrolysis. At the present time, however, hydrochloric acid is more commonly used. The starch in the form of a thin paste is subjected to the action of dilute hydrochloric acid under pressure. In a few moments the starch is converted into a mixture of dextrin and dextrose, in which condition it is used for the manufacture of the liquid material known in commerce as "glucose." A longer treatment with hydrochloric acid converts the dextrin into dextrose, and this is the form in which it is used in the manufacture of a solid sugar known as "grape sugar." After the conversion is completed, the hydrochloric acid is neutralized with soda, forming a little common salt, which does not interfere with the use of the glucose and grape sugar for the purposes for which they are used.

SUGAR MANUFACTURE.

In sugar manufacture we see even a more important utilization of chemical knowledge. Especially is this true of the beet-sugar industry. By means of chemical studies the sugar beet has been developed from the common garden beet, containing only 5 or 6 per cent of sugar, to its present condition of a root containing from 12 to 16 per cent. This great improvement has been secured solely by the aid of chemical science conjoined with the highest skill in practical agriculture. In the process of manufacture, however, chemical science has been even more successful. Beet juices, on account of their composition, present greater difficulties in manufacture than the juice of sugar cane. Without the aid of chemical science the present status of beet-sugar manufacture would have been impossible of attainment. Thus, through the exertions of chemistry, an industry has been established which has made a profound impress upon agriculture in general. Regions which are devoted to beet culture are everywhere known as those in which the highest form of scientific agriculture is practiced. Around the beet factory are naturally grouped vast dairy interests, where the cattle are fed upon the pulp from the diffusion batteries. The culture of beets implies the application of those principles of agricultural chemistry which secure an increase of the soil fertility. Every beet field, therefore, becomes a practical experiment station, where the best forms of agriculture are taught. All crops receive the benefits of this high culture, and thus, in these applications of the principles of practical agricultural chemistry, the general welfare of the agricultural interests of the community is secured. Perhaps there is no other instance in chemical technology where the application of scientific principles has proved of such signal advantage to the progress of agriculture.

WINE MAKING.

Wine making rests also largely upon chemical principles. In grapes we find large quantities of sugar combined with organic acids, of which tartaric acid is the chief, coloring matters, tannic principles, etc. The production of wine of fine flavor consists in securing the fermentation of the sugars of this mixture with appropriate ferments and under carefully controlled conditions of temperature. Only through the most careful chemical control are the most favorable conditions maintained. Consciously or unconsciously, the wine maker is a practical chemist, and under the influence of modern research the scientific principles of wine making are very much more firmly established and more easily practiced than they were before the conditions under which wine is produced were thoroughly understood. In wine making chemistry also exercises an important function in the utilization of the by-products. The tartaric acid present in grapes is very valuable in commerce, forming, in combination with potash, the well-known substance cream of tartar, which is so extensively employed in the manufacture of baking powders and for other purposes. By the application of the principles of chemical technology to the residues of the wine press and to the incrustations which form upon the vats the cream of tartar of commerce is secured.

BREWING.

Brewing is also largely a chemical science. The chief problem in the brewing industry is that of fermentation, and the development of fermentation has been due solely to the researches of chemists. In the brewing industry the first object is to convert the starch of the cereal into maltose and subsequently to change the maltose into alcohol by fermentation with yeast. By the researches of physiological chemists, it was discovered that the active principle in the conversion of starch into sugar is an enzymic ferment commonly called diastase, which is developed in barley by germination. This ferment rapidly converts starch into maltose, the conversion often taking place within a few minutes. By the researches of Pasteur and other distinguished chemists, the method of producing pure cultures of yeast was established. It is important, in order to secure a fine flavor to the finished product, that the ferment be as pure as possible. It is thus seen that in the chief problems which underlie the brewing industry chemistry takes a leading part.

DISTILLING.

The industry devoted to the manufacture of alcohol, whisky, and brandy is also chiefly of a chemical nature. The distilling industry naturally follows after the brewing industry. The manufacture of alcohol from starch may be described as the same in both industries. After the alcohol is formed it is separated from the mash by distillation. In spite, however, of the greatest care in the selection of yeasts, several varieties of alcohol as well as of organic acids are formed during the process of fermentation. After the distillation is finished, therefore, the separation of common alcohol from the impurities with which it is naturally mixed becomes a difficult chemical problem. The progress which has been made in this line, however, has been so great as to render the production of pure alcohol on a commercial scale an industrial proceeding of great magnitude. Chemical principles also of the utmost importance underlie the production of whisky and brandy, due to the elimination of objectionable alcohols by means of oxidations produced by storage under proper conditions of temperature and in suitable vessels. The whole process of aging a whisky or brandy or wine rests exclusively upon the proper conduct and control of the chemical reactions which take place.

TANNING.

The hides (at least indirectly) and also the principal part of the materials used in the process of tanning are products of the soil. Chemical technology has shown that in the process of tanning the gelatinous matters of which hides are composed are impregnated with tannic principles in such a way as to change their nature, rendering them insoluble in hot or cold water, resistant to atmospheric influences, flexible, and lasting. All these conditions are obtained by strictly chemical processes which have been carefully worked out. The relations of gelatin to tannin have been made the subject of the most careful chemical research. In like manner the utilization of the tannin-producing forests has been rendered much more economical. Formerly only the bark of the oak, the hemlock, and the chestnut was employed, but chemical science has shown that mixed with the fiber of the wood itself are tanning properties of a high value. In canaigre and other plants, chemical research has discovered sources of tannin that will take the place of tan bark, in the quest of which vast forests have been destroyed. Chemical technology has also taught the method of extracting from the bark and the wood their active principles, thus enabling dealers to transport the tannic principles in a condensed state and at a greatly reduced cost for freights. Almost all the great tanning industries of the country at the present time employ skilled chemists, and in many instances these chemists are directors of the factories.

FERTILIZER MANUFACTURE.

Perhaps chemical technology has rendered agriculture no other service so valuable as that which it has given in the development of the fertilizing industries of the world. The vast deposits of plant foods which occur in South America in the form of nitrate of soda, in Germany in the form of various combinations of potash, and in this country in deposits of mineral phosphates are made useful to agriculture only through the intervention of chemical technology. The earths saturated with nitrates in South America are treated chemically and the fertilizing principle obtained in a condensed form, making their economic transportation possible. The compounds of potash obtained in the mines near Stassfurt are subjected to chemical treatment, whereby the potash salts are concentrated and obtained chiefly in the form of sulphate and chlorid. The vast deposits of mineral phosphates furnish abundant materials which are subjected to treatment chiefly with sulphuric acid, and thus phosphoric acid is secured in a soluble form suitable for absorption by the growing plant. The wastes and offal of the cattle pens and abattoirs are collected and treated chemically and the nitrogenous and other fertilizing materials they contain secured in merchantable shape. Bones are subjected to mechanical and chemical treatment in order to render their phosphoric acid quickly soluble. Chemical technology has even established an intimate bond of union between agriculture and metallurgy. Iron ores that a few years ago were totally unfit for use by reason of the large amount of phosphorus they contained are now converted into the finest steel by new chemical processes which at the same time secure the phosphoric acid in the form of basic phosphatic slags, considered one of the most valuable phosphatic manures in use.

RELATION OF CHEMICAL TECHNOLOGY TO GENERAL AGRICULTURE.

In the above ways, the science of chemistry has offered to agriculture stores of plant food which a few years ago were totally inaccessible and useless. These stores are practically inexhaustible, since chemistry has shown that the atoms of plant food which are thus employed in the nutrition of the plant return after their cycle of life to the mineral state, only again to be made available for human nutrition. Chemistry in its relations to the technology of fertilizing materials has pointed out the way for indefinitely increasing the fertility of the soil and of laying forever the specter of starvation, which has so often been raised to threaten the future of mankind.

It is thus seen that chemical technology, while not directly concerned with the tillage of the fields, has done a wonderful work in establishing agriculture as a scientific profession and assuring its future against the principal dangers which menace it.

THE DEBT OF AGRICULTURE TO CHEMISTRY.

The foregoing sketch of the relations of chemical research to the progress of agriculture during the past hundred years presents an outline view of the status of this industry and its debt to science at the close of the nineteenth century. The true composition of the soil and its relations to plant growth are now known. The methods of utilizing plant food and of conserving it for the coming years have been fully established. The principles of plant growth and the chemical changes attending it are understood. The laws of animal nutrition have been experimentally elucidated, and by their application great economy in the use of nutrients is effected. The methods whereby organic nitrogen is prepared for plant food have been revealed, and some of the ways in which atmospheric nitrogen enters into organic combination are marked out. The application of the principles of chemical technology to the elaboration of raw agricultural products has added a new value to the fruits of the farm, opened up new avenues of prosperity, and developed new staple crops.

The closing of the century sees in this country an endowment for agricultural research which excites the admiration of the whole civilized world, and a study of the personnel of the scientific corps shows that fully half the amount expended for strictly scientific investigations has been for chemical studies. We find chemistry intimately associated with nearly every line of agricultural progress and pointing the way to still greater advancement.

When we contrast the condition of agricultural chemical knowledge which now obtains with the nebulous, empirical, and illogical theories which characterized it one hundred years ago, the distance we have traversed seems indeed long; but we should not forget that we are still only on the threshold of knowledge. The achievements of the next century ought to surpass those which the past one looks upon with pride.

To him who writes the story of the progress of agriculture as influenced by chemical research during the twentieth century may come a feeling of pity for the ignorance which now surrounds us; but he will at least accord to our workers the merit of being emancipated from the slavery of opinion and the worship of authority. He will certainly say they were patient, industrious, and truth loving. To the leaders of progress for the next century we commit our unfinished work, confident of their integrity and hopeful of the good which they will bring to mankind.

A REVIEW OF ECONOMIC ORNITHOLOGY IN THE UNITED STATES.

By T. S. Palmer,
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Introduction.

Economic ornithology has been defined as the study of birds from the standpoint of dollars and cents. It deals with birds in their relation to agriculture, horticulture, trade, and sport; it treats of species important to the farmer, the fruit grower, the game dealer, the milliner, and the sportsman; in short, it is the practical application of the knowledge of birds to the affairs of everyday life. The study of the relations of birds to agriculture is as intricate and difficult as it is broad and comprehensive. Its successful prosecution presupposes not only an accurate knowledge of classification, distribution, migration, and habits, but also an acquaintance with the measures which have been adopted for the preservation of useful or the destruction of noxious species. Theoretically, it should be one of the first branches of ornithology to receive attention; in reality, it has been one of the last.

DEVELOPMENT OF AMERICAN ORNITHOLOGY.

The history of American ornithology may be traced back to the middle of the sixteenth century, but for one hundred and fifty years the references to birds consisted of little more than fragmentary notes in the writings of early explorers and colonists. In the eighteenth century several important works appeared, the principal one being Mark Catesby's great work on the "Natural history of Carolina, Florida," etc., published in 1731–1743. One hundred and thirteen species of birds were described and figured, and the plates formed the basis of many of the species described by Linnæus a few years later. Important contributions were also made by Edwards, Forster, Latham, Bartram, Hearne, and Barton. Bartram's "Travels through North and South Carolina," 1791, marked the beginning of the distinctively American school of ornithology, and Barton's "Fragments of the natural history of Pennsylvania," 1799, was notable as the first exclusively ornithological book published in this country.

In the nineteenth century three names, Wilson, Audubon, and Baird, stand out with such prominence that they mark epochs in the development of the science. Wilson's "American ornithology," 1808–1814, laid the true foundation of ornithology in the United States;

Audubon's "Birds of America" and "Ornithological biographies," 1827-1839, occupy a field entirely alone, and Baird's "Birds of North America," 1858, published in conjunction with Cassin and Lawrence, made a great advance in all that relates to classification and nomenclature (the technical side of ornithology), and exerted a wider influence perhaps than any previous work. In the meantime the activity of travelers and explorers had added important contributions. The expeditions of Lewis and Clark across the continent in 1804-1806, of Long to the Rocky Mountains in 1819-20, and of Franklin to the Polar Sea; the travels of Douglas, Nuttall, Townsend, Maximilian, Audubon, and others; and, finally, the expeditions of the Pacific Railroad surveys opened up many new fields and brought to light a host of new birds from previously unknown regions in the West and North. The publication of Baird's work was followed almost immediately by a rapid increase in ornithological literature. The number of workers multiplied, and their contributions covered the whole field, from the brief description of a new species to elaborate faunal lists and comprehensive modern manuals, like those of Coues and Ridgway, which include all the birds of the continent from Mexico to the Pole. In 1883 the organization of the American Ornithologists' Union (an outgrowth of the Nuttall Ornithological Club, formed ten years previously) brought the individual workers in touch with one another and gave a new impetus to North American ornithology. The union prepared a code of nomenclature, which found general acceptance among zoologists, harmonized conflicting systems of classification, and published a new check list of birds. It stimulated research in every branch of ornithology, and by means of its quarterly journal, "The Auk" (now in its seventeenth volume), provided a place of publication and brought together in one series a large number of papers which otherwise would have been widely scattered.

Since the beginning of the century the field of North American ornithology has been extended from the Atlantic States to the Pacific, and from the Mexican boundary to Alaska and Greenland. The list of birds has increased 400 per cent, as shown by the number of species recognized by different authors: Wilson, in 1814, described 278 species; Audubon, in 1844, increased the list to 506; Baird, in 1858, recognized 738; Coues, in 1873, 778 species and subspecies; Ridgway, in 1880, 877; the "Check list" of the American Ornithologists' Union, in 1886, 951; and the additions since made have increased the number to about 1,125.

Compared with the activity in systematic work, the record of economic ornithology seems meager. The labors of American ornithologists were naturally directed at first to the discovery and description of new species and the acquisition of facts regarding their general habits and distribution; little attention was given to economic questions. Many notes concerning the food of birds may be found in the writings of

Wilson and Audubon, but there is little of importance outside of the works of these authors before the middle of the present century. The history of economic ornithology may be conveniently considered under three heads: (1) Investigations as to the value of birds; (2) commercial uses of birds; (3) measures for the destruction, preservation, and introduction of important species.

INVESTIGATIONS AS TO THE VALUE OF BIRDS.

The practical study of ornithology began to attract attention about 1850, and several papers appeared in the reports of the agricultural societies of Illinois and Ohio, as well as in the reports of the United States Commissioner of Patents. The character of some of these early contributions is indicated by such papers as Le Baron's "Observations on the birds of Illinois most interesting to the agriculturist" (1855), Walford's "Importation and protection of useful birds" (1855), Holmes' "Birds injurious to agriculture" (1857), Kirkpatrick's "Hawks and owls" (1858), and Dodge's "Birds and bird laws" (1865). Between 1860 and 1863 Dr. J. A. Allen prepared a series of twenty-five popular bird biographies entitled "Birds of New England," designed to interest farmers in common birds. In 1864 Elliott published an extended article on "Game birds of the United States," and during the next four years Samuels contributed three papers devoted largely to the birds of New England.

COMMENCEMENT OF INVESTIGATIONS ALONG MODERN LINES.

The first investigation along modern lines seems to have been made by Prof. J. W. P. Jenks, who, in 1858, studied the food habits of the robin and examined a considerable number of stomachs, collected at frequent intervals during the year.[1] Between March and September specimens were collected weekly and some of the time daily. Stomachs taken in March and April contained only insect matter, 90 per cent consisting of the larvæ of crane flies (*Bibio albipennis*). From May 1 to June 21 *Bibio* larvæ disappeared, but were replaced by a variety of insects, including caterpillars, elaterid beetles, and spiders. From late June to October the stomachs contained strawberries, cherries, and other fruits, but after October the vegetable diet was discarded and replaced by grasshoppers and orthopterous insects. The few birds which remained during the winter fed mainly on bayberries (*Myrica cerifera*), privet berries (*Ligustrum vulgare*), and juniper berries (*Juniperus communis*).

By a curious coincidence an experimental investigation of the robin was made in the same year (1858) by Prof. D. Treadwell. Two young birds, caught about June 5, were kept in captivity for the purpose of noting the amount of food eaten and the rate of growth from day to

[1] Trans. Mass. Hort. Soc., 1859.

day. One of the birds died after three days, but the other remained under observation for thirty-two days, when it had attained full size. "The fame of this robin has extended over both hemispheres." Its capacity for worms seemed unlimited. On the fourteenth day the worms eaten numbered 68, and their weight amounted to 41 per cent more than that of the bird, while their length, if laid end to end, would have measured 14 feet. Treadwell estimated that a pair of robins feeding a brood of four young at the rate averaged by this bird would have to collect 250 worms per day—an interesting illustration of the quantity of food consumed during the breeding season.[1]

In 1878 Prof. Samuel Aughey's classical paper, "Notes on the nature of the food of the birds of Nebraska," appeared in the First Annual Report of the United States Entomological Commission. It included observations extending over a period of thirteen years of 90 different species and an examination of more than 630 stomachs. The stomach contents were merely separated into grasshoppers, other insects, seeds, and miscellaneous, and the number of grasshoppers was given in each case. The report was the most extensive contribution to economic ornithology thus far published, and showed that grasshoppers, when abundant, become the principal food of insect-eating birds, and that they are largely eaten even by water birds.

In the meantime two entomologists had published their views on the relative value of birds and predaceous insects as insect destroyers. B. D. Walsh, State entomologist of Illinois, declared in 1867 that unless a bird destroyed at least thirty times as many noxious as beneficial insects it could not be considered a public benefactor.[2] The fallacy of this view was shown by Forbes, in 1880, in his "Interaction of organisms," and later by Weed.[3] In 1873 M. Edouard Perris called attention to the harm that birds might do in destroying parasitic hymenoptera, and stated that the utility of a bird depended on how many injurious insects it destroyed, usually an unknown quantity.[4] Forbes published a translation of this paper[5] seven years later, thus bringing it prominently to the notice of American ornithologists.

A PERIOD OF NOTABLE ADVANCE IN INVESTIGATIONS.

A notable advance was made in 1880 by Prof. S. A. Forbes, who first called attention to the relative value of the three methods of investigation now in general use, namely: (1) Field observation; (2) experiments on wild birds recently caught; (3) examination of stomachs in the laboratory. He also divided the food into three categories—injurious, neutral, and beneficial. Forbes's attention was confined

[1] Proc. Boston Soc. Nat. Hist., VI, pp. 396-399, 1859.
[2] Practical Entomologist, I[illegible] pp. 44-47, January, 1867.
[3] Proc. Fourteenth Ann. M[illegible]ing Soc. Promotion Agr. Sci., pp. 70-74, 1893.
[4] Bull. Mensuel Soc. Acclim [illegible] Paris, X, 1873.
[5] American Entomologist, III, pp 69 and 96, 1880.

mainly to thrushes, wrens, and bluebirds, of which he examined 320 stomachs, representing 9 species. His paper on the "Food of birds," printeded in the Bulletin of the Illinois State Laboratory of Natural History in 1880, is a model of thoroughness, and still remains the best report published on the food of the robin. A second paper on "The regulative action of birds upon insect oscillations," published in 1883, was devoted mainly to a discussion of the question whether insectivorous birds neglect their usual food for the sake of other insects which are unusually abundant, and a number of birds were collected during two successive years in an old orchard badly infested with cankerworms. These insects had attracted birds of the most varied character and habits to the orchard. An examination of 146 stomachs, representing 36 species, showed that 35 per cent of the food consisted of cankerworms.

About the same time appeared an elaborate investigation of the "Economic relations of Wisconsin birds," by Prof. F. H. King.[1] This report was chiefly remarkable for the large number of stomachs examined, more than 1,600, representing about 83 species, and the attempt to show graphically the percentage of the various elements of the food. It was the most extensive investigation thus far undertaken, but many species were represented by too small a number of stomachs to furnish satisfactory conclusions, and like Aughey's work in Nebraska, the identifications were rarely carried out in detail.

In Pennsylvania Dr. B. H. Warren has paid much attention to the food of birds, and has published the results of an examination of 2,084 stomachs, chiefly of grackles and birds of prey, in his "Birds of Pennsylvania," 1886. He has given special attention to the economic relations of hawks and owls, and in his reports as State zoologist and his "Enemies of poultry," 1899, has shown the evil results of the Pennsylvania "scalp act" of 1885. To his energy is due much of the credit of exposing the evils of bounty legislation on birds.

The destruction of birds and the causes of the decrease in bird life have been the subject of special study by Hornaday, who published in 1898 an important paper entitled "The destruction of our birds and mammals."[2]

Since 1886 economic investigations have been carried on chiefly with State or federal aid, and comparatively little has been undertaken by private individuals, except along special lines. Reference should here be made to the work of Forbush in connection with the gipsy moth commission of Massachusetts; to the detailed study of the food of the robin by Wilcox, who examined 187 stomachs collected during spring and summer;[3] and also to the studies of Prof. Clarence M. Weed, of the winter food of the chickadee (based on an examination

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[1] Wis. Geol. Surv., I, pp. 441–610, 1882.

[2] Second Ann. Rept. N. Y. Zool. Soc., pp. 77–126, 1898.

[3] Bull. 43, Ohio Agr. Expt. Station, pp. 115–129, 1892.

of 41 stomachs) and the habits of the chipping sparrow in feeding its young.[1]

The important researches thus briefly noticed include four investigations on the robin, an examination of 630 Nebraska birds, some 450 Illinois birds, about 1,600 Wisconsin birds, and an investigation of 2,084 birds of prey, grackles, and other species in Pennsylvania, comprising in all more than 5,000 stomachs.

WORK OF THE BIOLOGICAL SURVEY.

ESTABLISHMENT OF THE DIVISION.

One of the most important results of the organization of the American Ornithologists' Union was the impetus given to the study of economic ornithology. Committees on the English sparrow, bird migration, and geographical distribution were appointed at the first meeting, and elaborate investigations were at once begun. The work, however, had been planned on such a large scale that it soon outgrew the resources of the committees, and at the second annual meeting of the union it was determined to present a memorial to Congress to secure an appropriation for continuing it. The relation of birds to agriculture is so intricate and the thorough study of their food so difficult, on account of the amount of time and material required, that investigations of this kind are ordinarily beyond the means of private individuals, and are entitled to Government support. In recognition of the importance of the work, Congress granted an appropriation of $5,000, to be expended under the Division of Entomology of the Department of Agriculture, and on July 1, 1885, established a section of economic ornithology. Under the direction of Dr. C. Hart Merriam, investigations were outlined on a broad scale, to include the "food habits, distribution, and migrations of North American birds and mammals in relation to agriculture, horticulture, and forestry." A year later the section became an independent Division, and in 1896 its name was changed by Congress to the broader title of Division of Biological Survey.

FIRST PUBLICATIONS OF THE DIVISION.

Upon the organization of the Division of Ornithology and Mammalogy, the data collected by several of the committees of the American Ornithologists' Union were turned over to it and formed the basis of its first two bulletins. The notes on distribution and migration of birds were published in 1888 under the title "Bird migration in the Mississippi Valley," and the report on the "English sparrow in America" appeared in the following year. The latter report contained a full account of the sparrow and its introduction into the United States, its depredations on crops, and recommendations for destroying it, or at least preventing its increase. Special attention was called to the desirability of legislation permitting the destruction of the bird. It

[1] Bulls. 54 and 55, New Hampshire Agr. Expt. Station, 1898.

is interesting to note that at the time the bulletin was issued the English sparrow was practically protected by law in twenty-two States, although Ohio and Michigan had taken steps to exterminate it, while now most of the States have withdrawn protection, and Illinois, Michigan, Ohio, and Utah have vainly attempted to destroy the pest under the bounty system.

FUNCTIONS OF THE DIVISION FROM THE STANDPOINT OF ECONOMIC ORNITHOLOGY.

From the standpoint of economic ornithology the Division may be said to have three functions: (1) To determine as accurately as possible the food of birds of economic importance; (2) to act as a court of appeal to investigate complaints concerning depredations of birds on crops; (3) to diffuse the results of its work and educate the public as to the value of birds. In studying birds' food dependence is placed chiefly on examination of stomachs to ascertain what has been actually eaten. Stomachs are collected in different localities at all seasons and in sufficient numbers to show clearly the character of the food. The stomach contents are examined microscopically and identified by comparison with reference collections of seeds and insects. This laboratory examination is supplemented by experiment and field work.

INVESTIGATIONS REGARDING SUPPOSED INJURIOUS BIRDS.

Species popularly considered injurious, such as hawks and owls, the crow, blackbirds, woodpeckers, and blue jays, received attention first. A report on hawks and owls was undertaken by Dr. A. K. Fisher, one on the crow by Prof. W. B. Barrows, assisted by Mr. E. A. Schwarz in the identification of the insect material, while the investigations on the crow blackbird, woodpeckers, and blue jay were made by Prof. F. E. L. Beal.

The destruction of birds of prey in Pennsylvania, following the passage of the "scalp act" of 1885, had attracted widespread interest, and showed the necessity for correcting erroneous views concerning the value of hawks and owls. About 2,700 stomachs of these birds were collected, the contents carefully examined, and the results published in 1893 in a bulletin entitled "Hawks and owls of the United States," illustrated by twenty-six colored plates. Of the 75[1] species and subspecies which occur in America north of Mexico, only 6 were found to be injurious, while several were shown to be beneficial. About the time the work was begun bounties on birds of prey were, or had recently been, offered by Colorado, Indiana, New Hampshire, Ohio, Pennsylvania, Virginia, and West Virginia. At present not only have all the important State bounties been withdrawn (the acts

[1] Ninety species and subspecies are now recognized by the Check List of the American Ornithologists' Union, but if species of accidental occurrence and the less important subspecies are omitted, the number is reduced to about 75. Of these, food examinations of about 45 species have been made by the Division.

still in force are mainly local), but several States have adopted protective measures. New Hampshire and Ohio began with eagles, Rhode Island with fishhawks, and New York and Minnesota with owls. Pennsylvania and Alabama now protect all except the six or seven really injurious species, while during the present year Utah has gone so far as to make it unlawful to kill any hawks or owls. Such changes show the gradual appreciation of the value of these really useful birds.

In the case of the crow, nearly 1,000 stomachs were examined, and the charges of pulling up sprouting corn, of injuring corn in the milk, of destroying fruit, and of destroying eggs of poultry and wild birds were all sustained. But it was found that corn in the milk formed only 3 per cent of the total food, and most of the corn destroyed was waste grain; that the destruction of fruit and eggs was trivial, while, on the other hand, many noxious insects and mice were eaten. The verdict was therefore rendered in favor of the crow, since, on the whole, the bird seemed to do more good than harm.

Similar studies of crow blackbirds (based on about 2,300 stomachs) and woodpeckers (including nearly 700 stomachs), published in 1895, showed that these birds were decidedly beneficial. Only 1 of the 7 species of woodpeckers examined—the yellow-bellied—exhibited any questionable traits, namely, a fondness for the sap and inner bark of trees. Of the 40 or 50 birds, exclusive of hawks and owls, thus far investigated, the English sparrow is the only one which has been condemned.

INVESTIGATIONS REGARDING BENEFICIAL BIRDS.

A number of species usually considered beneficial have also received attention. The Baltimore oriole, meadowlark, cuckoos, red-winged blackbird, rose-breasted grosbeak, cedar bird, robin, bluebird, swallows, and several flycatchers have been studied by Professor Beal, and the shrikes, sparrows, catbird, mocking bird, brown thrasher, and house wren by Dr. Sylvester D. Judd. One of the interesting facts brought out in studying the catbird was the discovery that some birds prefer wild to cultivated fruits, so that the latter may be protected by planting certain berry-bearing shrubs and trees, especially in regions where wild fruit is naturally scarce. The kingbird, frequently condemned as a destroyer of honey bees, was shown to eat very few bees, and these mostly drones. On the other hand, it kills many of the destructive robber flies, and a large proportion of its food is made up of injurious insects, so that it must be regarded as decidedly beneficial. Recent investigations show less favorable results in the case of some other flycatchers, and indicate that the prevailing idea that all insectivorous birds are necessarily very beneficial may require decided modification; and that there are birds which habitually feed on beneficial insects to such an extent as to lower their value to the farmer, if not to place them among the enemies of his crops.

RESULTS OF FOURTEEN YEARS' WORK.

As a result of fourteen years' work the Biological Survey has brought together a collection of about 32,000 bird stomachs, of which some 14,000 have been examined. It has investigated about 100 species (nearly half hawks and owls) and prepared the results for publication in the form of bulletins or special papers. The publications on birds already issued include seven special bulletins,[1] fifteen papers in the Annual Reports for 1886–1893, inclusive, and eight papers in the Yearbooks for 1894–1898. Some of these papers, such as "Seed planting by birds," "Hawks and owls from the standpoint of the farmer," "Birds that injure grain," and "Birds as weed destroyers," deal with general topics of special interest. The investigations on some 30 grain and insect-eating birds were summarized in 1897 for a bulletin entitled "Common birds in their relation to agriculture," and the work of the Division has also formed the basis of two important summaries, one by Miss Florence A. Merriam, entitled, "How birds affect the farm and garden,"[2] the other by Professor Beal, on "Economic relations of birds and their food."[3]

The educational work of the Biological Survey has not been confined to laboratory studies or publications. The Division has prepared exhibits to illustrate the food habits of birds and modern methods of investigation for the expositions at Cincinnati in 1888, Chicago in 1893, Atlanta in 1895, and Nashville in 1897. It indorsed the proposition to establish a "Bird day" in the schools in 1894, and issued a circular on the subject two years later. Ever since its organization it has acted as a bureau of information on all subjects relating to birds or their distribution and habits. In short, it has spared no effort to advance the cause of economic ornithology in every possible way.

Commercial Uses of Birds.

Birds are utilized in a variety of ways. Some species are valuable for food, a few as egg producers, others for plumage for millinery purposes, and still others for their guano. An immense trade has sprung up in game, feathers, and guano, and our markets draw their supplies from all parts of the world. Aside from its purely commercial aspect, this traffic is important in its relation to agriculture. Most game birds are useful to the farmer, and their preservation is important not only because of this fact and on account of their market value, but also for the purpose of protecting smaller insectivorous species which otherwise are likely to be destroyed to supply the

[1] No. 1, English Sparrow, 1889; No. 2, Bird Migration in the Mississippi Valley, 1888; No. 3, Hawks and Owls, 1893; No. 6, Common Crow, 1895; No. 7, Food of Woodpeckers, 1895; No. 9, Cuckoos and Shrikes, 1898; and Farmers' Bulletin, No. 54, Some Common Birds in Their Relation to Agriculture, 1897.

[2] Forest and Stream, XLVII, pp. 103, 123 and 144, 1896.

[3] Proc. Twenty-fourth Ann. Meeting N. J. Hort. Soc., 1899.

increasing demand for game. The millinery trade has already practically exterminated several native species, and as plume birds become scarce insectivorous birds are utilized in increasing numbers. Finally, to the development of the guano trade, agriculture owes much of the advance which has been made in the modern system of intensive cultivation and the intelligent application of fertilizers.

GAME.

Accurate statistics regarding birds and bird products are difficult to obtain, but the increase in this trade has had a marked, and in some cases a disastrous, effect on certain native species. The number of birds annually killed for game in the United States has increased largely with the development of railway systems and the perfection of cold-storage facilities for shipping game to market. Quantities of game are frequently kept in cold storage for months at a time, or even from one season to another, so that our large cities can now receive their supplies not only from neighboring regions but from distant States and even foreign countries; for instance, South American tinamous, shipped from Argentina to London, and then imported into this country, have been sold in the markets of Washington, D. C., having thus been necessarily kept on ice for several months. New York, Baltimore, Boston, Chicago, St. Louis, New Orleans, and San Francisco are all large game centers, and the quantity of birds annually sold in any one of these cities is simply enormous. D. G. Elliot, writing as long ago as 1864, states that one dealer in New York was known to receive 20 tons of prairie chickens in a single consignment, which were estimated to represent 20,000 birds, and that some of the larger poultry dealers sold from 150,000 to 200,000 game birds in the course of six months. "These estimates," he adds, "so far from being exaggerated, are probably far below the true state of affairs, and these, it must be recollected, are but the receipts of a single city. The total number of birds destroyed throughout the country would exceed the credibility of everyone."[1]

The consumption of game to-day is much greater than it was thirty-five years ago, and the effect of such enormous slaughter has become very apparent in the case of several species, as for example, the pinnated grouse, or prairie hen, and the passenger pigeon. The prairie hen (*Tympanuchus americanus*) occurs on the prairies of the Mississippi Valley from Louisiana and Texas, north to latitude 50° in Manitoba, and from northwestern Ohio and southwestern Ontario to central Nebraska and Kansas. In the east its range is rapidly contracting; a few are still found in Kentucky, but the species is rare in Indiana and northwestern Ohio. It usually lays from 11 to 14 eggs in a set, and is considered one of the most prolific of game birds,

[1] Rept. Comm. Agr., 1864, pp. 383 and 384.

ranking next to the bobwhite in this respect. But in spite of this and the fact that the bird is gradually extending its range westward with the settlement of the country, the species can not maintain its normal abundance in the face of the destructive agents against which it has to contend.

Audubon states that when he first moved to Kentucky (about 1808) prairie hens were very abundant, and could be seen frequently in the farmyards with the poultry and even in the streets of the villages. So little were they esteemed as game that hunters scarcely deigned to shoot them, and they could hardly be sold for more than a cent apiece. A quarter of a century later he remarks that the grouse had practically abandoned the State of Kentucky, and each year their limit of abundance was moving farther westward.[1] A few are still found in the State and in many sections of the prairie region of adjoining States, but they are no longer abundant east of the Mississippi River.

A still more striking case of extermination is that of the passenger pigeon (*Ectopistes migratorius*), which has been reduced almost to the point of extinction except in two or three Northern States. This species formerly ranged over the deciduous forest region of Eastern North America, from the Gulf of Mexico to Hudson Bay, and was remarkable for the enormous numbers which often collected together. To-day its breeding range is restricted to the thinly settled wooded region along the northern border of the United States, chiefly in Michigan and Wisconsin. It was one of the first birds to attract the attention of the early colonists, and references to it may be found as far back as 1630.[2] The enormous breeding colonies and roosts and the great flights, such as that seen by Audubon in 1813, afforded an abundant supply of food, and the birds were slaughtered by the million. Audubon speaks of seeing schooners at the wharves in New York in 1805 that were loaded in bulk with pigeons taken on the Hudson River, and states that the birds sold for only a cent apiece. In March, 1830, he found them so abundant in the New York markets that piles of them could be seen in every direction. He purchased 350 live pigeons at 4 cents apiece, most of which were carried to England. Prof. H. B. Roney has described a breeding colony located near Petoskey, Mich., in 1878, which covered about 100,000 acres of land, and from which it was estimated 1,500,000 dead birds and 80,532 live birds were shipped by rail, and probably an equal number by water. He estimates the total destruction of pigeons in Michigan in 1878 at 1,000,000,000, an estimate probably in excess of the number actually killed.[3]

The passenger pigeon has long since ceased to have any commercial importance; the netting and the slaughter to which it was subjected

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[1] Ornith. Biog., II, p. 491, 1835.

[2] See Merriam's Birds of Connecticut, pp. 93-94, 1877.

[3] Am. Field, X, pp. 345-347.

at its roosts and breeding grounds have almost exterminated it. According to Brewster, the last important nesting in Michigan took place in 1881, a few miles west of Grand Traverse.[1] In the last twenty years the species has decreased so rapidly that its occurrence in any of the States except Indiana, Michigan, Minnesota, and Wisconsin can hardly be considered more than accidental. During the last ten or twelve years a few flocks of a hundred or more have been reported from the following places:

Large flocks of passenger pigeons reported between 1889 and 1899.

Date.	Locality.	Estimated number.	Authority.
1889, September 10	Mackinac Island, Mich	100	White, Auk, X, p. 223.
1894, spring	Hickory, Minn	500	Gault, *ibid.*, XII, p. 80.
1896, May 22	Constableville, N. Y	300	Johnson, *ibid.*, XIV, p. 88.
1897, August 17	Cook, Nebr	100	Deane, *ibid.*, XV, p. 184.
1898, October 3	Ann Arbor, Mich	200	Covert, Recreation, X, p. 304.
1899, April 10	Litchfield, Ohio	150	Scudder, *ibid.*, X, p. 488.
1899, May 15	Norway, Wis	200	Eagan, *ibid.*, XI, p. 221.
1899	Sparta, Wis	500	Dervin, *ibid.*, XI, p. 221.
1899	Montport, Wis	300	Collis, *ibid.*, XI, p. 221.

Smaller flocks or single birds have also been reported from Illinois (Chadwick, 1899; Lake Forest, 1895; Marengo, 1894); Indiana (several points, 1894–1896); Kentucky (Cobb Station, 1898); Maryland (several points, 1893); Massachusetts (Norton, 1889); Missouri (Altie, 1896); New Jersey (Englewood, 1896; Morristown, 1893); Pennsylvania (Potter County, 1892). Although the wild pigeon is now protected by law at all seasons in Michigan and Ohio, it is doubtful whether it can be saved from extinction. Like the bison, it has been sacrificed through wasteful and useless slaughter.

EGGS.

Large colonies of water birds, such as murres, pelicans, gulls, terns, and herons, may be found at certain points along our coasts during the breeding season. The value of these birds has never been properly appreciated, although in certain localities eggs of some species are highly esteemed and find a ready market, as on the eastern shore of Virginia, where eggs of the laughing gull (*Larus atricilla*) are considered a great delicacy and are gathered in large numbers for sale to hotels and private individuals. But in the gratification of this taste there is the same tendency toward extermination, which is manifested in the case of feather collecting.

Scott refers to the extermination of gulls and terns near the mouth of Tampa Bay, Florida, brought about in part by the operation of the

[1] Auk, VI, pp. 285–291, 1889.

Collecting Albatross Eggs on Laysan Island, H. I.

[Photograph by J. J. Williams, Honolulu.]

market egg hunters in the early eighties.[1] Sennett, in speaking of the quantities of eggs, chiefly of gulls, terns, and herons, gathered a few years ago along the coast of Texas, says:

> There is probably not a port, pass, or bay on the entire coast of Texas whose inhabitants do not regularly devote several days each year to what they term "egging." * * * All eggs from an inch in diameter upward are taken, excepting perhaps those of the pelican, whose eggs are too fishy for any stomach. I have known of boats which came a distance of over 100 miles to gather these eggs, cruising from reef to reef until they secured a good load. For days after the return from these expeditions the shops along the coast expose quantities of birds' eggs for sale, which are disposed of cheaply, according to size. * * * In regard to the profits of the "egging business," I doubt if even the most successful "egger" can make as much money as he could have done had he stuck to his regular and much more praiseworthy occupation.[2]

The eggs of the "arrie" or "Pallas" murre (*Uria lomvia arra*) are collected for food on the Pribilof Islands, in Bering Sea, and H. W. Elliott mentions that on the occasion of his first visit to Walrus Island, in July, 1872, six men in less than three hours loaded a badarrah carrying 4 tons with eggs to the water's edge.

On Laysan, one of the northwestern Hawaiian Islands, the "gooney," or albatross (*Diomedea immutabilis*), fairly swarms. Immense quantities of its eggs are gathered for the use of the employees of the guano company, and possibly some are shipped to Honolulu. Photographs show that the eggs are gathered not only by the wheelbarrow load but by the car load. (See Pl. VI.) Formerly, it is said, the birds were accorded rigid protection by the superintendent of the company, but how long they can survive the recent wholesale removal of eggs is not difficult to surmise.

A still more striking example of wholesale egg collecting, and probably the most important one in the United States from a financial standpoint, is that of the Farallones. These islands, or rather rocks, situated on the coast of California 30 miles west of the Golden Gate, are the breeding grounds of myriads of sea birds, chiefly western gulls (*Larus occidentalis*) and murres, or California guillemots (*Uria troile californica*). For nearly fifty years murre eggs were collected here and shipped to the San Francisco market, where they found a ready sale at from 12 to 20 cents per dozen, a price only a little less than that of hens' eggs. During the season, which lasted about two months, beginning near the middle of May, the eggs were shipped regularly once or twice a week. The main crop was gathered on South Farallone, the principal island, and mainly from the "great rookery" at the west end. The bird lays only one egg, which is deposited on the bare rock. When the season opened, the men went over the ground and broke all the eggs in sight, so as to avoid taking any that were not perfectly fresh. The ground was then gone over every second day, and the eggs were systematically picked up and shipped to market.

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[1] Auk, V, p. 377, 1888.

[2] Science, VII, pp. 199-200, February 26, 1886.

The business was in the hands of Italians and Greeks, who were also engaged in fishing, and although only a dozen or fifteen "eggers" were employed on the islands, the number of eggs gathered was simply enormous. It is said that in 1854 more than 500,000 were sold in less than two months, and that between 1850 and 1856 three or four million were taken to San Francisco. Dr. Heermann states that the value of the traffic was between $100,000 and $200,000, evidently too large an estimate, even at the high price of eggs prevailing at that time. Since then the value of the eggs has declined, and the number has also fallen off considerably. In 1884 there were gathered 300,000; in 1886 about 108,000; while in 1896 the crop was reduced to a little less than 92,000.

The Farallones being a Government light-house reservation, the "eggers" were allowed on the islands only by sufferance. From 1850 to 1880 the Farallone Egg Company remained in almost undisputed sway, but were dispossessed in 1881 by the light-house authorities. Afterwards the keepers employed men to gather the eggs, but in 1897 the attention of the Light-House Board was called to the decreasing numbers of birds, and instructions were promptly issued prohibiting further gathering of eggs for market, thus practically putting an end to the business for the present. Full accounts of the methods employed in this remarkable traffic may be found in the interesting papers of Bryant and Loomis,[1] from which the above facts have been mainly derived.

FEATHERS.

The fashion of wearing feathers and birds on hats has increased to such an extent during recent years as to cause an immense demand for birds and plumes to supply the millinery trade. The saying that a bird which has become fashionable is doomed to almost certain extinction is exemplified by the great decrease in numbers of terns along the Atlantic coast and herons of the Gulf States within the last twenty years. Attention was called to this wholesale destruction by the American Ornithologists' Union in 1886,[2] and the devastation of the Florida heronries and the barbarous methods of the plume hunters were vividly described by Scott in 1887 in a series of papers entitled "The present condition of some of the bird rookeries of the Gulf coast of Florida."[3]

Terns of several species were formerly abundant along the coast from Florida to New England. The common tern (*Sterna hirundo*) and the least tern (*S. antillarum*) bred abundantly on the New Jersey coast, but, according to Stone, both were nearly exterminated about 1883 to supply the millinery trade. As an example of the wholesale destruction of birds, Scott mentions a contract made by two men on Tampa Bay, Florida, for the delivery of 30,000 terns in a single

[1] Proc. Cal. Acad. Sci., 2d ser., I, pp. 31–36, 1888; VI, pp. 356–358, 1896.
[2] Science, VII, pp. 191–205, 1886.
[3] Auk, IV, pp. 135, 213, 273, 1887.

season. Similar contracts have been made on the coast of Virginia; and from Seaford, Long Island, N. Y., more than 3,000 terns were sent to market during the summer of 1883 by one gunner and his associates, while about the same time 40,000 are said to have been killed on Cape Cod, Mass. The results of such slaughter were swift and sure. An examination of the grounds about the mouth of Tampa Bay and the bars off Pass Agrille, on the west coast of Florida, in the summer of 1888 showed that not a tern of any kind was breeding where countless numbers had nested only a few years before.[1] Of the northern coast, Chapman says in 1895 "this little barren, uninhabited sand island [Gull Island, off Long Island]—only a few acres in extent—and Muskeget Island, off the Massachusetts coast, are the only localities from New Jersey to Maine where the once abundant common tern, or sea swallow, can be found in any numbers. [Each of these islands now has a keeper who is paid to protect the terns.] What an illustration of the results of man's greed and woman's thoughtlessness!"[2]

But the destruction of herons has been, if possible, even worse. The only heron feathers of any value are the nuptial plumes, commonly known as aigrettes, and in order to secure these plumes at their best the birds are killed on the breeding grounds soon after the eggs are laid or the young hatched. As the herons nest in colonies, it is often an easy matter to kill a large number by the use of rifles of small caliber. The American egret (*Ardea egretta*) and the snowy egret (*A. candidissima*) furnish the finest aigrettes, and consequently have suffered most severely; to-day the latter species is the rarest heron in the South.

Scott speaks of finding herons abundant in 1880 at a number of large rookeries on the west coast of Florida, but in 1886 the same breeding grounds were almost deserted or marked by piles of dead and decaying birds. The slaughter which had begun at least two years before was then still under way, and a price had been set on every bird of any value to the plume hunters. One man who had visited Florida for four seasons was employing from 40 to 60 gunners, to whom he furnished supplies and paid from 20 cents to $2.50 apiece for desirable skins, the average price being about 40 cents. Besides the plume birds, such as herons, ibises, and roseate spoonbills, various others—sandpipers, plovers, turnstones, least terns, boat-tailed grackles, gray king birds, and even owls—were killed for the Northern market.[3] "I have heard a 'plume hunter,'" says Chapman, "boast of killing 300 herons in a rookery in one afternoon. Another proudly stated that he and his companions had killed 130,000 birds—herons, egrets, and terns—during one winter. But the destruction of these birds is an unpleasant subject. It is a blot on Florida's history."[4]

[1] Scott, Auk, V, p. 376.

[2] Birds East. N. Am., p. 82.

[3] Auk, IV, pp. 141 and 277.

[4] Birds East. N. Am., pp. 133-134.

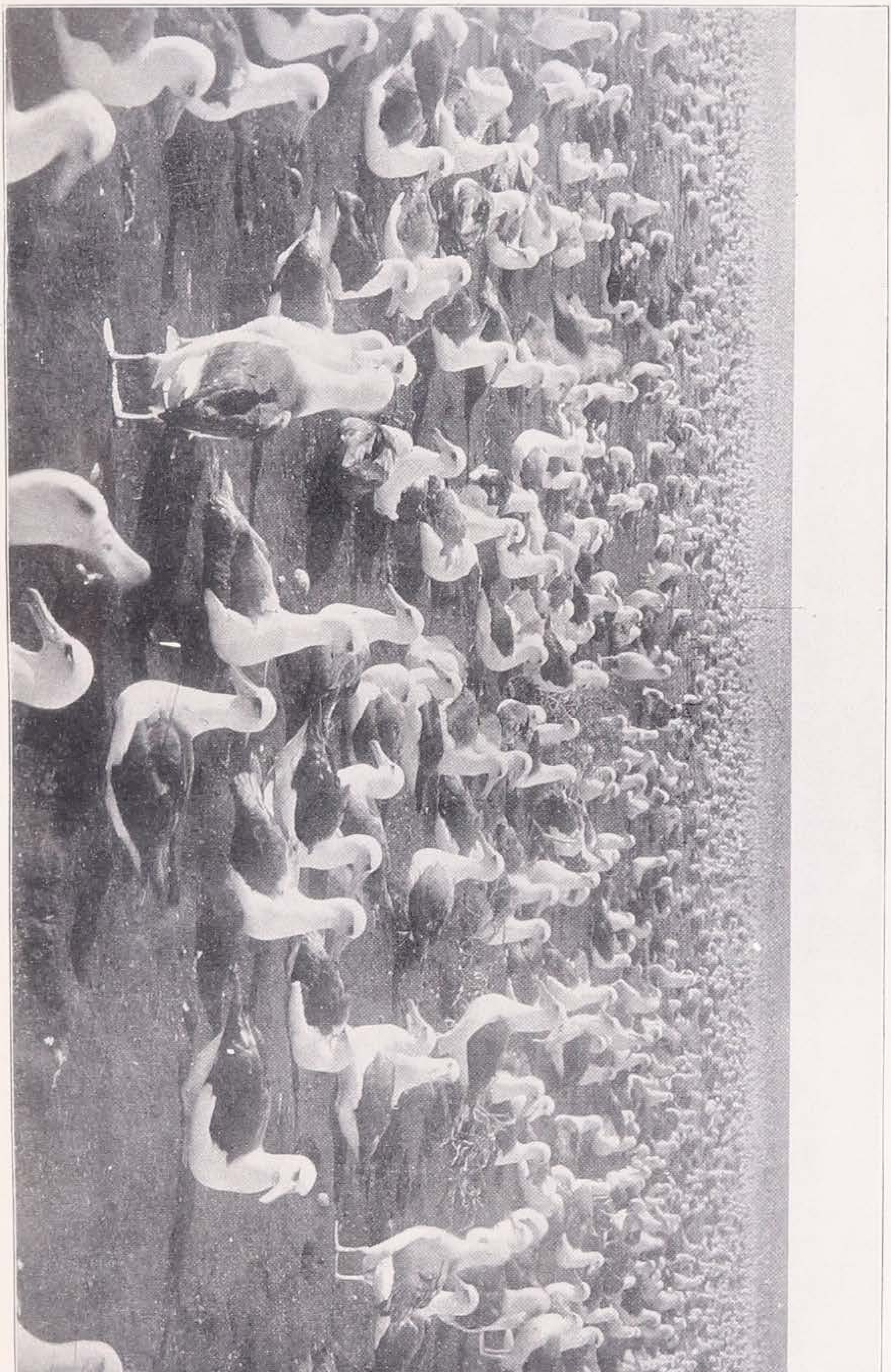
Unfortunately, the demands of the millinery trade are not confined to plume birds and terns or to any particular State, and the slaughter so destructive to the Florida herons is being repeated in less degree in several sections of the country in the case of other birds.

Among the few redeeming features of the feather trade should be mentioned the establishment of a new industry through the introduction of the South African ostrich (*Struthio australis*). The first birds, 22 in number, reached New York in December, 1882, and a few months later were placed on a farm near Anaheim, Cal. In 1899 there were several ostrich farms in southern California, and one each in Arizona, Florida, Texas, and the Hawaiian Islands. Although ostrich farming in the United States has passed through many vicissitudes and is still in its infancy, the important fact has been demonstrated that ostrich feathers can be produced in this country which are equal to the best grades imported from abroad.

GUANO.

Alexander von Humboldt, returning from his extended travels in tropical America in 1804, carried to Europe some samples of bird dung, or guano, and first called attention to the value of the extensive deposits of this substance on the Chincha Islands, off the coast of Peru. The announcement excited little interest at the time, but its importance was realized forty years later, when guano revolutionized methods in agriculture and furnished a new source of revenue for corporations, and even nations, chief among the latter being Peru, which for several years depended largely on the income from the Chincha Island deposits to pay the interest on her national debt. In the early fifties guano became the subject of diplomatic correspondence between the United States and Peru and Venezuela; but the negotiations failing to secure the desired reduction in price of Peruvian guano, deposits were sought elsewhere. Finally, Congress was induced to take action, which resulted in the taking possession by private persons under the protection of the United States of a number of small guano islands in the West Indies and in the South Pacific.

Deposits of the excrement of sea birds occur on rocky islands in various parts of the world in nearly all latitudes; but guano of commercial value is limited chiefly to the rainless regions of the Tropics, usually within a few degrees of the equator. Its fertilizing value lies in the presence of nitrogen, phosphates, and a small amount of potash. Under a tropical sun the excrement dries rapidly and undergoes little change, whereas in moist climates fermentation speedily sets in, resulting in a loss of nearly all the organic matter, while the soluble alkalies and phosphates are leached out. Guano may therefore be divided into two main classes: (1) Nitrogenous, represented by Peruvian guano, which has undergone little change; (2) phosphatic,



ALBATROSSES (DIOMEDEA IMMUTABILIS) ON LAYSAN ISLAND, H. I.

[Photograph by J. J. Williams, Honolulu.]

represented by Baker Island guano, which has lost everything of manurial value except the insoluble phosphate of lime.[1]

Concerning the species of birds to which we owe these valuable deposits, comparatively little accurate information is available, chiefly because most of the islands are mere rocks or reefs, uninhabited and inaccessible, and seldom visited by ornithologists. Laysan Island, in the Hawaiian group, which has been thoroughly explored, is known to be the resort of myriads of albatrosses (Pl. VII), man-o'-war birds, pelicans, tropic birds, gannets, terns, and petrels. Besides these species, shearwaters, gulls, and penguins occur in immense numbers on some of the islands off South America and Africa.

The importance of guano as a fertilizer was recognized by the Peruvians more than three centuries ago. Under the Incas it was held in such high esteem that the deposits on the Chincha Islands were jealously guarded, and the birds which resorted to these rocks were carefully protected. Indeed, it is said that the penalty of death was inflicted on anyone killing the birds near the deposits during the breeding season. Guano was the first of the artificial manures to be used in large quantities, and hence may be said to have brought about the modern system of intensive cultivation. The earliest experiments with it in the United States seem to have been made in December, 1824, with samples from 2 barrels distributed by Hon. John S. Skinner, editor of the American Farmer.[2] Its introduction into England in 1840 was due to Lord Derby. So rapidly did it increase in favor that ten years later the imports amounted to 200,000 tons. It is estimated that this total has since grown to more than 5,000,000 tons. At the inception of the export trade in guano from the Chincha Islands, about 1840, the supply seemed inexhaustible. The deposits covered the three islands in some places to a depth of 90 or 100 feet, estimated at 12,376,100 tons, according to an official survey made by the Peruvian Government in 1853. But so great was the demand for the new and powerful soil stimulant that this enormous quantity has now been practically exhausted.

The extraordinary demand caused a rapid increase in the price. By 1850 it had advanced in the United States to $50 or more per ton, and negotiations were opened with the Peruvian Government in the hope of securing a reduction in the rate. Failing to attain the object in this way, American enterprise began to seek guano elsewhere, and in 1854 the deposits on the Aves Islands, in the West Indies, were taken possession of by a Boston firm. Venezuela promptly seized the islands, but after some correspondence abandoned her claim. Meantime, in September, 1855, the American Guano Company of New York was organized, with a capital of $10,000,000, for the purpose of

[1]Aikman, Manures and Manuring, pp. 296–300, 1894.

[2]American Farmer, VI, pp. 316–317, 1824.

developing the deposits on Baker and Jarvis islands, in the South Pacific; and on August 18, 1856, Congress passed an "act to authorize protection to be given to citizens of the United States who may discover guano,"[1] under which any citizen of the United States was authorized to take possession of and occupy any unclaimed island, rock, or key containing guano, upon filing a notice of such claim and a bond to insure compliance with the requirements of the law. The discoverers of such islands were entitled to exclusive rights to the deposits thereon, but the guano could only be removed for the use of citizens of the United States and at a price not exceeding $8 per ton alongside the vessel, or $4 per ton on the spot. Imports were subject to the laws governing the coasting trade of the United States, and the Government was relieved from the necessity of protecting or retaining possession of any island, rock, or key after the guano had been removed. Thus far, claims have been filed to about seventy-five islands in the Caribbean Sea and the South Pacific, as shown by the following list:

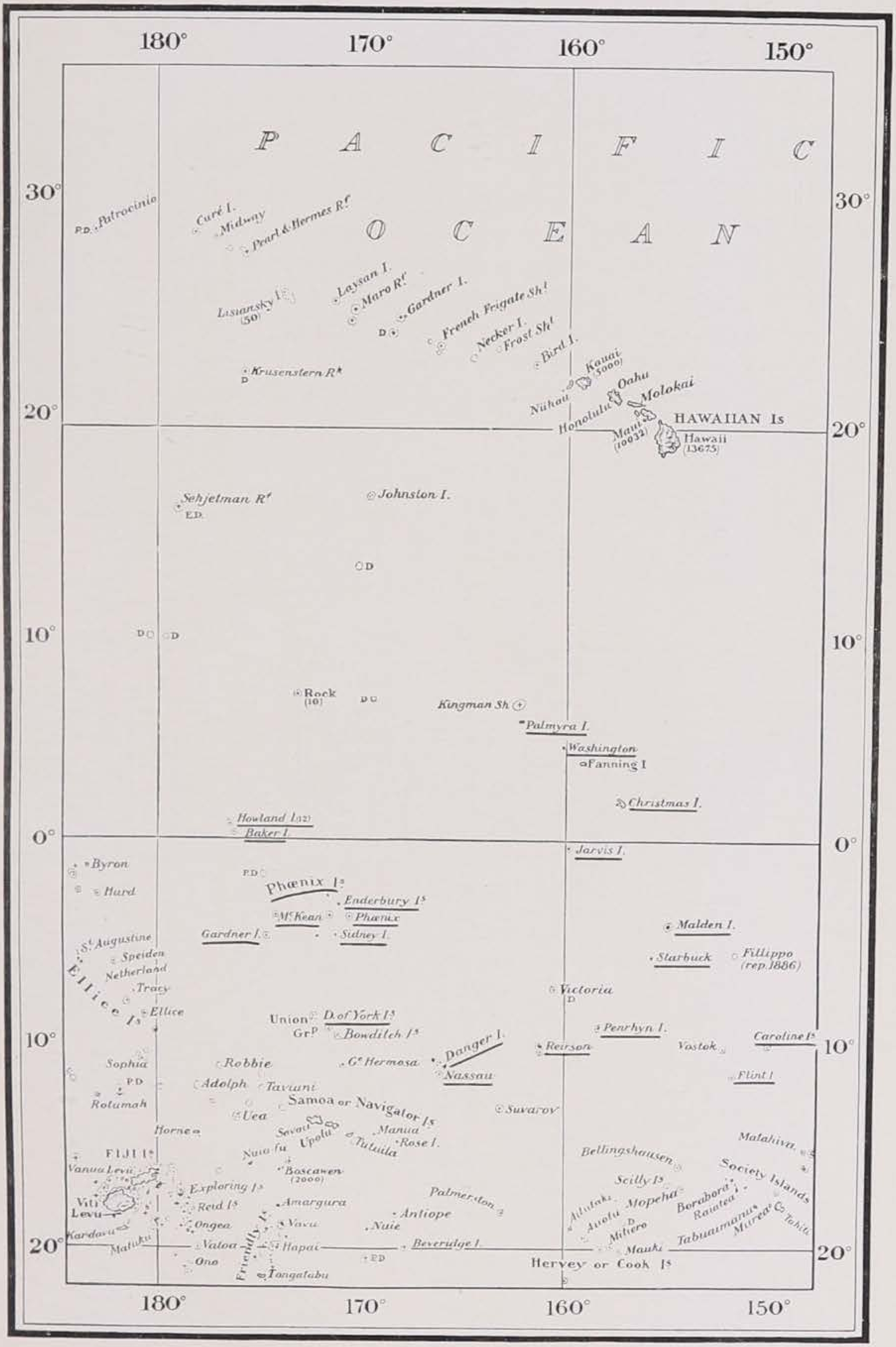
List of guano islands now appertaining to the United States.[2]

[Bonded under act of August, 1856.]

PACIFIC ISLANDS.

Name.	Latitude.	Longitude.	Name.	Latitude.	Longitude.
	° ′	° ′		° ′	° ′
America	3 40 N.	159 28 W.	Groninque	10 00 S.	156 44 W.
Anne	9 49 S.	151 15 W.	Howland, or Nowland	0 52 N.	176 52 W.
Baker, or New Nantucket	15 N.	176 30 W.	Humphrey	10 40 S.	160 52 W.
Barber	8 54 N.	178 00 W.	Jarvis	0 21 S.	159 52 W.
Barren, or Starve	5 40 S.	155 55 W.	Johnston	----------	----------
Bauman	11 48 S.	154 10 W.	Kemn	4 41 S.	173 44 W.
Birnie	3 35 S.	171 39 W.	Lideron	11 05 S.	161 50 W.
Caroline	9 54 S.	150 07 W.	Low	9 33 S.	170 38 W.
Christmas	1 58 N.	157 10 W.	McKean (Phœnix group)	3 35 S.	174 17 W.
Clarence	9 07 S.	171 40 W.	Mackin	3 02 N.	172 46 W.
Dangerous	10 00 S.	165 56 W.	Malden	4 00 S.	155 00 W.
Dangers Rock	6 30 N.	162 23 W.	Mary Letitia	4 40 S.	173 20 W.
David	40 N.	170 10 W.	Mary	2 53 S.	172 00 W.
Duke of York	8 30 S.	172 10 W.	Mathew	2 03 N.	173 26 W.
Enderbury (Phœnix group)	3 08 S.	171 08 W.	Nassau	11 30 S.	165 30 W.
Farmer	3 00 S.	170 50 W.	Palmyra	5 48 N.	162 20 W.
Favorite	2 50 S.	176 40 W.	Penrhyn	8 55 S.	158 07 W.
Flint	10 32 S.	162 05 W.	Pescado	10 38 S.	159 20 W.
Flints	11 26 S.	151 48 W.	Phœnix	3 40 S.	170 52 W.
Frances	9 58 S.	161 40 W.	Prospect	4 42 N.	161 38 W.
Frienhaven	10 00 S.	156 59 W.	Quiros	10 32 S.	170 12 W.
Gallego	1 42 N.	104 05 W.	Reirson	10 10 S.	160 53 W.
Ganges	10 59 S.	160 55 W.	Rogewein	11 00 S.	156 07 W.
Gardner (Phœnix group)	4 40 S.	174 52 W.	Samarang	5 10 N.	162 20 W.
			Sarah Anne	4 00 N.	154 22 W.

[1] 11 Stat. L., 119. [2] From data on file in the Treasury Department.



PRINCIPAL GUANO ISLANDS IN THE PACIFIC OCEAN (BONDED UNDER ACT OF 1856).

[From Chart 923 of the United States Hydrographic Office. Names of bonded islands underlined.]

List of guano islands now appertaining to the United States—Continued.

PACIFIC ISLANDS—Continued.

Name.	Latitude.	Longitude.	Name.	Latitude.	Longitude.
	° ′	° ′		° ′	° ′
Sidney (Phœnix group)	4 20 S.	171 00 W.	Walker	3 58 N.	149 10 W.
Starbuck, or Hero	5 25 S.	155 56 W.	Washington, or Uahuga	4 40 N.	160 07 W.
Staver	10 05 S.	152 16 W.			

WEST INDIES.

	° ′	° ′		° ′	° ′
Anchor Key	14 18 N.	80 08 W.	North Rocks	14 20 N.	80 26 W.
Aves	15 40 N.	63 37 W.	Pedro Keys	17 00 N.	77 52 W.
Booby Key	14 14 N.	80 30 W.	Petrel	15 52 N.	78 33 W.
Great and Little Swan	17 23 N.	83 50 W.	Quito Sereno	14 30 N.	81 07 W.
Morant Keys (Northeast, Sand, Savanna, Seal)	17 26 N.	77 55 W.	Roncador	13 33 N.	80 03 W.
Navassa	18 10 N.	75 00 W.	Serrana Key	14 15 N.	80 24 W.
North Keys	14 25 N.	80 20 W.	Serranilla Keys (East, Middle, Beacon)	15 20 N.	79 40 W.
			Triangle Keys	14 20 N.	80 05 W.

Fifty-four of these islands are in the Pacific Ocean (see map, Pl. VIII), the remainder in the Caribbean Sea or the Gulf of Mexico. Of the Pacific islands, Baker and Jarvis were bonded in 1856, Howland in 1858, Barren, Christmas, Enderbury, Johnston, McKean, Malden, and Phœnix in 1859, and the others in 1860. The Pacific islands[1] are situated between longitude 150° and 178° W., the most northern being the Johnston Islands, latitude 16° 53′ N.; the most southern, Bauman, latitude 11° 48′ S. Most of them are between the Society and Hawaiian islands, and are chiefly small coral reefs, a mile or two in length, almost entirely destitute of vegetation. One of the most northern guano deposits, which has been successfully developed, is that on Laysan, a small island 3 miles long by 2½ broad, in latitude 26°, which has recently been acquired through the annexation of Hawaii.

As would naturally be supposed, the extent and value of some of the deposits were at first greatly exaggerated, while others proved to have little value, and, as in the case of the Alacran Rocks, in the Caribbean Sea, were afterward abandoned. In an interesting article on the Pacific guano islands, Hague, who had visited a number of them, states that the first cargoes of guano brought from the Johnston Islands proved to be sand; that samples of guano from Christmas Island were chiefly coral sand, and that the deposits on Starbuck, or Hero, consisted of hydrated sulphate of lime. Some of the islands are covered with vegetation, and hence unsuited for the deposition of guano, while others, such as David, Farmer, Favorite, Flint, Samarang, Sarah Anne, and Walker, Hague considered as probably nonexistant, at least in the

[1] Except Gallego, which is in the eastern Pacific in longitude 104° 05′ and northwest of the Galapagos Islands.

positions usually assigned them on charts.[1] Still, during the thirty years from 1869 to 1898, 283,871 tons of guano, valued at $3,229,832, were brought from the islands appertaining to the United States. The production was very irregular, varying from a minimum in 1890 of 1,176 tons, worth $9,577, to a maximum in 1878 of 17,930 tons, valued at $211,239. The returns for each year are shown in the following table:

Guano brought from islands appertaining to the United States for the years ending June 30, from 1869 to 1898, inclusive.[1]

Year.	Tons.	Value.	Year.	Tons.	Value.	Year.	Tons.	Value.
1869	15,622	$253,545	1880	12,795	$147,051	1891	15,857	$101,918
1870	17,068	392,172	1881	16,883	179,882	1892	4,288	26,032
1871	14,154	240,235	1882	15,249	160,016	1893	4,376	26,256
1872	4,209	60,865	1883	7,873	92,130	1894	5,137	31,190
1873	11,014	161,690	1884	9,333	106,431	1895	8,082	48,164
1874	6,877	160,345	1885	12,100	86,166	1896	6,929	37,374
1875	7,269	122,012	1886	5,770	38,839	1897	5,310	31,860
1876	14,785	192,972	1887	8,226	55,671	1898	4,562	27,372
1877	6,060	79,822	1888	5,765	41,226	Total	283,871	3,229,832
1878	17,930	211,239	1889	10,439	72,643			
1879	8,733	95,137	1890	1,176	9,577			

[1] Data furnished by the Bureau of Statistics, Treasury Department. The returns for 1889 to 1898 are published in "Commerce and Navigation of the United States," p. 690, 1899.

Besides the guano deposits belonging to the United States, there are others in various parts of the world, among which may be mentioned those along the coast of Lower California, on the Galapagos, and, the most important of all, the Chincha Islands in latitude 13° 38′ S., Guanape, Lobos, and others belonging to Peru. Valuable deposits have been found along the coasts of Venezuela, Colombia, Ecuador, and Bolivia. Guano has also been obtained from Shark Bay and Swan Island, Australia; Algoa Bay and Saldanha Bay, Cape Colony; Ascension and Ichaboe islands, off the west coast of Africa, and Kuria Muria, on the Arabian coast. Some of the best deposits have now been exhausted; those which remain are expensive compared with the better artificial fertilizers now in use; but a small amount of guano is still brought from some of the islands and imported from abroad, a reminder of the important trade of forty or fifty years ago.

Measures for the Destruction, Preservation, and Introduction of Birds.

A review of the progress of economic ornithology would scarcely be complete without some reference to the attempts which have been made to destroy injurious birds or to increase beneficial species. Naturally, attention was first directed to the damage done by birds to crops, and bounties were paid for the destruction of the marauders. Later, as the

[1] Am. Journ. Sci., XXXIV, pp. 224–243, 1862.

country became settled and the value of birds better appreciated, attempts were made to protect useful species, and also to introduce other species that were thought desirable. The subject may therefore be considered under three heads: (1) Measures for the destruction of birds—bounty laws; (2) measures for the protection of birds—game laws; and, (3) introduction of foreign birds.

MEASURES FOR THE DESTRUCTION OF BIRDS—BOUNTY LAWS.

Efforts have been made since colonial days to exterminate certain birds considered injurious to agriculture. The early settlers, seeing their crops attacked by crows, blackbirds, and ricebirds, undertook measures for bird destruction long before they thought of bird protection. Among the various relief measures were the curious scalp-tax acts, which were intermittently in force in Virginia for more than seventy years subsequent to 1734, and which required a certain number of bird scalps each year in lieu of taxes. In most localities, however, the apparently simple expedient of drawing on the county or State treasury for the payment of rewards was more popular and more generally adopted. Sixteen or more States (all but two east of the Missouri River and north of latitude 36°) have waged a desultory warfare against crows, blackbirds, hawks, owls, certain fish-eating birds, and English sparrows. Crow bounties have been offered in eight States, mainly along the Atlantic seaboard; hawk bounties in ten, chiefly in the Middle States and in those along the Great Lakes, premiums on blackbirds in Minnesota and New Jersey; on fish-eating birds in Utah, and on sparrows in Illinois, Michigan, Ohio, and Utah.

Until recently depredations on grain crops were the main cause of hostility to birds; and the crow was the principal object of attack down to the latter part of the present century. In 1805 a crow-scalp tax was in force in Virginia, under which taxpayers in five counties were required to deliver three crow scalps annually or pay a penalty of 4½ cents for each missing scalp. In 1826 a premium of 8 cents on crows was paid by some of the counties of Virginia, and two years later by the whole State. Meantime, Delaware had authorized the creation of a crow-bounty fund in Newcastle County as early as 1810, and New Hampshire had established a premium of 12½ cents on crows in 1817–1819. Some years later New Hampshire reestablished the rewards, and subsequently offered premiums of 10 cents in 1829, 1832–1835, and 1849–1851. Maine followed next with an 8-cent bounty, which was in force from 1830 to 1834. The only recent crow bounties of consequence are those of New Hampshire (1881–1883) and Maine (1889–1891)—10 cents in each case.

From the earliest colonial times down to 1875 crows, blackbirds, and bobolinks, or ricebirds, had been the main, if not the only, subjects of adverse legislation, but in that year Delaware established the precedent of paying premiums on hawks and owls by offering 50 cents for all species except "fishhawks and mouse owls." These hawk bounties, which were very popular during the succeeding fifteen years, have probably done more harm than any others. In 1877 Delaware's example was followed by Colorado with an act offering a 25-cent bounty on hawks (in force until 1885) and by New Hampshire with one offering a 20-cent bounty (in force until 1881). West Virginia followed in 1881, Indiana in 1883, and Virginia in 1884. Finally, in 1885, Pennsylvania passed its famous scalp act, which resulted in such large expenditures and such glaring frauds that it attracted widespread attention, and was repealed eighteen months later. Since then hawk and owl bounties have been far less popular, and the acts which still remain on the statute books of three or four States are practically dead letters, being enforced in only a few localities.

In 1887 attention was turned to the English sparrow as a legitimate subject for bounty legislation. Michigan began by paying 1 cent apiece for sparrows, and two years later increased the amount to 3 cents. Utah offered one-fourth of a cent apiece and Ohio 10 cents per dozen in 1888, and both States doubled their rewards in 1890. Illinois has paid 2 cents since 1891 on all English sparrows killed in December, January, and February. In 1896 Utah increased its bounty, allowing 1 to 3 cents, and established a rate of 5 cents per dozen on eggs. Sparrow bounties are still maintained in these four States, and have resulted in large expenditures; but they have not exterminated the English sparrow or even caused a perceptible diminution in its numbers except in a few localities. On the other hand, these bounties have caused the destruction of a large number of native sparrows, which have been killed for the sake of the rewards.

A dangerous precedent has recently been set by Utah in placing premiums on fish-eating birds, such as fishhawks, herons, mergansers, pelicans, and loons, in the interest of owners of fish ponds and hatcheries. The act has not been in force long enough to have much effect, but experience in Europe has shown the abuses to which such laws are subject and the evils in which they are likely to result.

The following table contains a list of the principal bounty laws on birds which have been in force during the century; local acts, such as the township bounties in Michigan, and the special county bounties in Maryland, Virginia, and one or two other States, are omitted:

Principal bounty laws on birds in force from 1800 to 1899.

State.	In force.	Species.	Remarks.
Colorado	1877–1885	Hawks	25 cents.
Delaware	1810	Crows	Newcastle County.
	1847–1852	....do	4 cents, March to September.
	1852–1873	....do	4 cents.
	1875–1877	Hawks and owls	50 cents (fishhawks and "mouse owls" excepted).
Illinois	1891–1899	English sparrows	2 cents, December to February.

Principal bounty laws on birds in force from 1800 to 1899—Continued.

State.	In force.	Species.	Remarks.
Indiana	1883-1899	Hawks and owls	Not exceeding $2 (sparrow hawks and screech owls excepted).
Kansas	1889	Crows	Crawford County.
Maine	1830-1834	do	8 cents.
	1889-1891	do	10 cents, April to October.
Maryland		Crows and hawks	
Michigan	1869		Township bounties authorized.
	1887-1899	English sparrows	1 cent; 1889, 3 cents; 1895, 2 cents; November to March since 1893.
Minnesota	1885	Blackbirds	
	1887	do	10 cents per dozen, April to June; 5 cents, July to October.
New Hampshire	1817-1819	Crows	12½ cents.
	1829	do	10 cents, April to June.
	1832-1835	do	10 cents, March 20 to July 20.
	1849-1851	do	10 cents, April 15 to June 15.
	1877-1881	Hawks	20 cents.
	1893-1897	do	25 cents.
New Jersey		Blackbirds, crows	
Ohio	1881-1882	Hawks	50 cents.
	1882-1883	Hawks and horned owls.	50 cents ("hen, chicken, or bird hawks" only).
	1888-1899	English sparrows	10 cents per dozen; since 1890, 20 cents per dozen.
Pennsylvania	1885-1887	Hawks and owls	50 cents.
Utah	1888-1899	English sparrows	½ cent; 1890, ¼ cent; 1896, 1 to 3 cents, eggs, 5 cents per dozen.
	1896-1899	Fishhawks, herons, fishducks, loons.	10 to 25 cents; since 1897, 25 cents.
Virginia	1826-18—	Crows	8 cents; 5 counties in 1826; general in 1828.
	1849-18—	Blackbirds, crows.	
	1884-1899	Chicken hawks and owls.	50 cents (screech owls excepted).
West Virginia	1881-18—	Hawks and owls	

It has been deemed expedient to review this legislation in detail in order to correct the misapprehension that bounty laws are few in number or unimportant. More than forty such laws on birds have been in force during the century, but, besides the Pennsylvania scalp act and a few others, very little information is accessible concerning them. There is still a general demand for bounties on certain birds, as taxpayers ordinarily know little about the cost or the results of such legislation.

Though the average bounty law seldom remains in force more than two or four years, it may prove a costly experiment and do much harm. Maine spent more than $12,000 in her two attempts at crow extermination in 1830–1834 and 1889–1891, Illinois more than $55,000 for English sparrows in 1891–1896, Michigan about $61,800 for English sparrows in 1887–1895, and Pennsylvania about $90,000 for hawks and owls in 1885–1887. Altogether it is safe to say that the systematic destruction of birds in this country during the century has cost more than $250,000, and most of this money has been spent by half a dozen States during the last fifteen years. Since the exposure of the evils of the Pennsylvania scalp act there has been a tendency to repeal bounties on useful birds of prey, and so far as possible, to provide against fraud. Premiums on crows and blackbirds have been practically abandoned, and almost the only important ones still in force are those on the English sparrow.

MEASURES FOR THE PROTECTION OF BIRDS—GAME LAWS.

It was said some years ago that the United States had done less for the protection of its birds than any other civilized country. If this is still true, it certainly is not because of lack of legislation, for nearly all the States have enacted game laws, and frequently changed them as their defects have become apparent. Statutory law is notoriously erratic and unstable, and with forty-eight States and Territories, each attempting to protect its game in its own way, confusion has naturally arisen. Protective measures have rarely, if ever, fulfilled expectations, and consequently game and insectivorous birds have continued to decrease. Federal legislation has been advocated as the only remedy, but its feasibility is questionable, since the jurisdiction of Congress in ordinary cases extends only to the Territories and Government reservations.

The need of protective measures has long been recognized, and although the uniformity attained by other countries has not been secured in the United States, definite progress has been made, as will be seen from the following brief review: In the present century Massachusetts, as early as 1818, enacted a law for the preservation of game birds; Virginia in 1832 prohibited the killing of wild fowl at night on the water and forbade the use of swivel guns; in 1850 Connecticut and New Jersey protected insectivorous birds; and in 1857 Ohio passed a comprehensive law protecting both game and insectivorous birds and eggs of all species, and prohibiting the sale of game birds during close seasons. By 1864 similar laws were in force in all the States south to Maryland and west to Minnesota, excepting West Virginia and Indiana, and also in California. Several of these acts related solely to game birds, and those of Illinois and Maryland were enforced only in certain counties.[1] At the present day practically all the States and Territories endeavor to protect game, and most of them extend protection to insectivorous birds.

CRITICISM OF GAME LEGISLATION.

Game laws have suffered in popular estimation because they have not been systematically enforced; because, as sometimes alleged, they

[1] Dodge, Rept. Comm. Agr., pp. 442–446, 1864.

are enacted for selfish ends, and because they lack stability and uniformity. The enactment of a game law is only a beginning, and unless some one is charged with seeing that its provisions are carried out, it is almost certain to be a failure; nor can it be entirely successful unless supported by public sentiment. The appointment of salaried game wardens has overcome the first difficulty to some extent.

Credit for much that has been accomplished in protective legislation is due to sportsmen and game associations, but their efforts have not always been appreciated, and have even been misconstrued from the belief that other interests have been overlooked. The relation of the sportsman to the farmer was aptly stated in the State senate report on the Ohio game bill of 1861, as follows:

> The genuine and honorable sportsman is the friend and ally of the agriculturist. He will be found always ready to protect birds which are useful, destroy the rapacious and hurtful, to prevent trespasses, and enforce the laws.[1] * * * The pursuit of game can not be prevented, and it is useless to attempt it. It should be regulated, and for this purpose the highest skill and knowledge of the habits of birds and wild animals should be employed, the most reasonable and perfect rules established by statute, and all should unite in their rigid enforcement. Any other system will result in disappointment and failure.

The principles on which such statutes should be based were defined as (1) protection of useful birds, other than game, at all seasons; (2) protection of game birds in such manner as to promote their reasonable increase; (3) withdrawal of protection from species of doubtful value; (4) use of well-known names in the statutes to avoid confusion.[2] Another common criticism is that game laws are subject to frequent change. This is, unfortunately, true, but there have been notable exceptions, such as the act recently repealed in the District of Columbia, which remained in force twenty-one years, and the Indiana and Louisiana statutes of 1881 and 1877, respectively, which are still in force. However, permanency without effectiveness is of little value.

EFFORTS AT UNIFORMITY IN GAME LAWS.

Repeated efforts have been made to bring about greater uniformity in the various State laws, including those protecting insectivorous birds. The International Association for the Protection of Fish and Game, organized in May, 1875, and comprising representatives from thirty-eight States and Territories and Canada, prepared in 1877 a simplified code of cooperative laws for presentation to State legislatures, but then allowed the matter to drop. Between 1890 and 1896 half a dozen conferences of State commissions were held, but they

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[1] This relation is exemplified by the Connecticut Association of Farmers and Sportsmen for the Protection of Fish and Game, which has for its objects not only the preservation of game and the enforcement of game laws, but also the protection of farmers against trespassers and marauders who tear down fences or injure stock. This association has been in existence ten years.

[2] Collins, Fifteenth Ann. Rept. Ohio Board Agr. for 1860, pp. 383, 390, 1861.

accomplished little of permanent value, although at the Saratoga meeting of 1896 no less than thirteen States were represented. In the following year the "Hallock Code" of cooperative legislation was advocated by Mr. Charles Hallock. This scheme divides the United States into three "concessions"[1] (a northern and southern, comprising States, respectively, north and south of latitude 36° 30' and east of the Rocky Mountains; and a Pacific, including the region west of the Rocky Mountains), in each "concession" the laws to be as uniform as possible, the open seasons identical, and protection to be given insectivorous birds, but withheld from blackbirds, bobolinks, crows, hawks, owls, cormorants, pelicans, and English sparrows.[2]

To a certain extent this idea was carried out by a convention of game wardens and delegates from six Northwestern States held at Chicago in February, 1898, which drafted a bill for the protection of birds and game and agreed to urge its adoption by the respective State legislatures. This bill was enacted by Illinois in 1899.

As an illustration of the present lack of uniformity in game laws and the desirability of some such expedient as that provided by the Hallock Code, the accompanying diagram (fig. 3) has been prepared, showing the months in which woodcock (*Philohela minor*) may be killed in the United States. It will be noticed that twelve States have no protective laws for this species, so that the birds can be killed at any season; that while some States, like Michigan and North Dakota, limit the open season to six weeks, others extend it to six months or more; and that in the South where the birds winter and begin to breed early and thus need protection most, protective measures are least effective. The States are arranged in two groups, as suggested in the Code.

SPECIAL RESTRICTIONS.

Game laws, pure and simple, when properly enforced, may be very effective, as is well shown in the increase of such resident birds as quail and introduced pheasants. Both species are occasionally protected by close seasons of several years' duration, and the open seasons are usually short, that for quail averaging scarcely more than two or three months. There seems to be a general impression that migratory birds are so abundant that they require less protection, and hence the open seasons for them are usually longer, those for ducks ordinarily being five months or more. The result is becoming very obvious in the recent marked decrease of these birds. It is interesting to note that forty years ago the same plea was made regarding the passenger pigeon, now practically exterminated. In a discussion of the Ohio law of 1861 it was said the bird needed no protection.

[1] "We call it 'concession,' because it is based on compromise and reciprocity."—HALLOCK.

[2] Address before the National Game, Bird, and Fish Protective Association, 1897 (see Western Field and Stream, I, pp. 232–234, 1897).

The passenger pigeon needs no protection. Wonderfully prolific, having the vast forests of the North as its breeding grounds, traveling hundreds of miles in

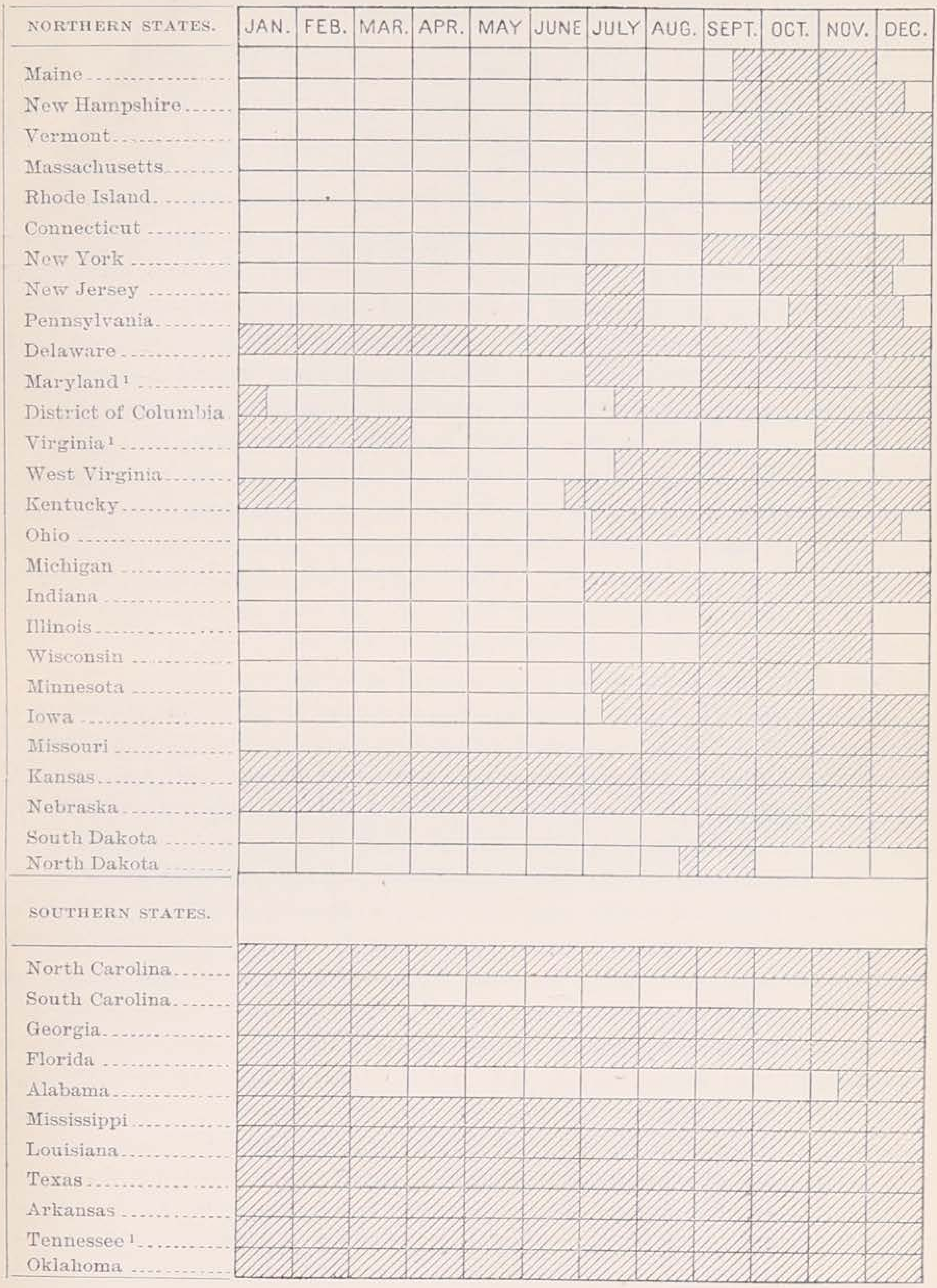

FIG. 3.—Diagram illustrating lack of uniformity in game laws, as shown by laws protecting woodcock (*Philohela minor*) in force in 1899: The unshaded area shows the months when woodcock are protected; the shaded area, the open seasons when shooting is permitted by law.

search of food, it is here to-day and elsewhere to-morrow, and no ordinary destruction can lessen them, or be missed from the myriads that are yearly produced.

[1]Local regulations in some counties provide a different season from that fixed by State law.

* * * The snipe, too, like the pigeon, will take care of itself, and its yearly numbers can not be materially lessened by the gun. The wild goose does not, perhaps, need general protection, though if any linger here till near breeding time they should be spared.[1]

The chief causes of the decrease in game birds are spring shooting, cold-storage traffic, and sale (during the close season) of birds imported from other States. Of late years attention has been directed toward the markets as the chief factor in game destruction, and in order to prevent undue slaughter, the traffic in game has been restricted more closely. Since the constitutionality of nonexport laws was established by the Supreme Court in 1896,[2] nonexport clauses have been quite generally incorporated in game laws, and the shipment of game from one State to another is now restricted or prohibited in more than half the States. Subjecting cold-storage rooms to inspection has been advocated, and laws limiting the quantity of game that may be killed in a day or a season were enacted by Iowa, Minnesota, and Pennsylvania in 1897, and Colorado in 1899. Killing game for sale was prohibited by law in Tennessee in 1889, and in Iowa and Pennsylvania in 1897. It has even been suggested that the sale of game should be prohibited at all seasons. This suggestion, advocated in 1894,[3] seems to have met with some favor, for it was incorporated in the laws of Kansas and Vermont two or three years ago, and has been taken up by the League of American Sportsmen.

The necessity for restricting the list of game birds is still very urgent in certain States. In the markets of New Orleans everything that has feathers seems to be regarded as legitimate game. In some States robins, flickers, meadowlarks, and reedbirds are important items of game, and in California, where true reedbirds do not exist, no less than a dozen species of native sparrows and finches, masquerading under the name of reedbirds, have been identified in the markets of San Francisco. This difficulty is met by the "Act for the protection of birds," proposed early in 1886 by a committee of the American Ornithologists' Union, which limits game birds to the Anatidæ—swans, geese, and ducks; Rallidæ—rails, coots, and gallinules; Limicolæ—plovers, snipe, woodcock, sandpipers, and curlew; and Gallinæ—turkeys, grouse, pheasants, and quail. Species not included in these four groups are protected at all seasons, but provision is made for collecting specimens for scientific purposes. This act was practically adopted by New York in 1886, by Indiana in 1891, and by Illinois in 1899. With its exact definition of game birds and its protection of all other species, it does away with the difficulties attendant upon the enforcement of laws protecting "song" or "insectivorous" birds and obviates the necessity for special acts protecting species that do not properly come within either of these groups. Florida and

[1] Collins, Fifteenth Ann. Rept. Ohio Board Agr. for 1860, p. 387, 1861.

[2] Geer v. State of Connecticut, 161 U. S. 519.

[3] Forest and Stream, XLII, p. 89.

Texas have special acts prohibiting the killing of "birds of plume," such as herons, egrets, and ibises; Maine, one prohibiting the killing of terns; Maryland, Michigan, Oregon, Utah, and Virginia protect gulls; several States, notably Alabama, Illinois, Pennsylvania, and Utah, have begun to protect birds of prey, and a majority of States now protect "insectivorous" birds. The uniform adoption of the proposed act would greatly simplify legislation.

PROSPECT FOR ENFORCEMENT OF GAME LAWS.

With the present widespread interest in birds, there is every reason to hope that in future laws will not be allowed to become dead letters. Fish and game commissions, sportsmen's associations, Audubon societies, farmers, and the general public are all interested in the cause of bird protection.[1] In January, 1898, the League of American Sportsmen was organized for the special purpose of enforcing game laws and protecting song and insectivorous birds. This association, which is composed of representative sportsmen in all parts of the United States, advocates the propagation of game and the enactment of laws licensing guns, limiting the killing of game, and prohibiting the sale of game at all seasons.[2]

INTRODUCTION OF FOREIGN BIRDS.

Much interest has been manifested in importing song birds and game birds from other lands to supplement the list of native species or replace those which are rapidly decreasing. Neither expense nor failure prevents the frequent repetition of such experiments, although scarcely half a dozen of the thirty or forty introduced species have really become acclimated in the United States. Besides the English sparrow and the European tree sparrow, a score or more kinds of song birds and ten or twelve of game birds have been imported at various times.

The introduction of the English sparrow (*Passer domesticus*) is one of the most familiar examples of acclimatization. Brought over to the United States in 1850, the bird developed such a marvelous ability to adapt itself to new surroundings and increased so rapidly that by 1870 it had gained a foothold in twenty States and the District of Columbia, as well as in two provinces of Canada. At the present time it is found in every State and Territory except Alaska, Arizona, Montana, Nevada, and New Mexico. It is known everywhere as a great pest, and Illinois, Michigan, Ohio, and Utah are now offering bounties for its destruction.[3] The closely related European tree

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[1] For list of State officials and associations concerned with the protection of birds and game, see Appendix.

[2] Recreation, VIII, p. 233, 1898.

[3] A full account of the habits and distribution of the English sparrow may be found in Bulletin No. 1, Division of Ornithology and Mammalogy, 1889; see also the Yearbook of the Department of Agriculture for 1898, pp. 98–101.

sparrow (*Passer montanus*) has been introduced at St. Louis, Mo., but has never spread to any extent. Twenty birds were imported in 1870, and the species is well established in the country immediately about the city. It is much less objectionable than the English sparrow, and is said to lack the fighting qualities which have made the latter bird so unpopular.

Importation of song birds from Europe began about the middle of the century. Thomas Woodcock, president of the Natural History Society of Brooklyn, is said to have brought over a number in 1846, and the following season goldfinches, linnets, bullfinches, and skylarks were seen at Greenwood and in the suburbs of Brooklyn. The last species survived two winters.[1] Early in 1853 John Gorgas liberated 42 skylarks at Wilmington, Del., and a number were set free at Washington, D. C.[2] Allen states that in 1853 a considerable number of skylarks, wood larks, English blackbirds and other thrushes, robin redbreasts, and goldfinches were set at liberty in Greenwood Cemetery, New York.[3]

Between 1872 and 1874 the Acclimatization Society of Cincinnati, Ohio, spent about $9,000 in importing some 4,000 European birds, belonging to about 20 species, but the experiment resulted in failure. At nearly the same time the Society for the Acclimatization of Foreign Birds liberated at Cambridge, Mass., a considerable number of European goldfinches (*Carduelis carduelis*) and other species. About 1877 a number of starlings (*Sturnus vulgaris*) were set free in Central Park, New York, by the American Acclimatization Society. This was followed by several similar experiments, only the last of which, in 1890, when 60 birds were released, seems to have been successful. Goldfinches set at liberty at Hoboken, N. J., in 1878, appeared in Central Park, New York, in the following year, and were found breeding in 1886.[4] In 1889 and 1892 the Society for the Introduction of European Song Birds, of Portland, Oregon, imported two lots of birds at a cost of about $2,000. Some 20 species were represented, including 50 pairs of skylarks, 30 pairs of black thrushes, 35 pairs of starlings, and 15 pairs of green linnets. As a result of these numerous importations, the European tree sparrow has become established in the vicinity of St. Louis, Mo.; the European goldfinch has been found at various times in several places in eastern Massachusetts and in Central Park, New York; the skylark has become acclimated on Long Island, N. Y., and in the vicinity of Portland, Oregon; the starling is slowly spreading up the lower Hudson Valley and has also gained a foothold at Portland; a few other species are reported to be doing well in Oregon, but all the rest have failed to survive.

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[1] Forest and Stream, XI, p. 406, 1878.

[2] Rept. Comm. Patents for 1853 (Agr.), pp. 70–71.

[3] Bull. Nuttall Orn. Club, V, p. 120, 1880.

[4] Adney, Auk, III, pp. 409–410, 1886.

The introduction of game birds has been far more successful than that of song birds. The species include the English pheasant (*Phasianus colchicus*), the ringneck or Mongolian pheasant (*P. torquatus*), the green pheasant (*P. versicolor*), the golden pheasant (*Chrysolophus pictus*), the silver pheasant (*Euplocomus nycthemerus*), the capercailzie (*Tetrao urogallus*), the black grouse or black game (*Lyrurus tetrix*), the migratory quail (*Coturnix coturnix*), the partridge (*Perdix cinerea*), the Indian black partridge, and the sand grouse. Of these, the most important are the English and Mongolian pheasants.

The Mongolian and other Asiatic pheasants were sent to Oregon from China by Judge O. N. Denny, formerly consul-general at Shanghai, and the first importation was apparently made in 1881. Most of the birds died on the way and only 15 (12 males and 3 females) reached Portland alive. These were liberated at the mouth of the Willamette River, about 12 miles below the city. The second lot, received in 1882 (?), comprised 35 or 36 ringnecks, which were set at liberty 12 miles east of Albany, in the Willamette Valley. Nineteen ringnecks were also liberated in 1882 at Victoria.[1] Golden and silver pheasants were imported two or three years later and, with some ringnecks, were placed on Protection Island, near Port Townsend, Wash.[2] These four colonies all flourished, and from them birds were carried to other parts of the Pacific coast. The Mongolian did far better than the others, and increased so rapidly that in 1891, when complete protection was removed, they had spread over a considerable part of western Oregon. English pheasants have been imported mainly in the Eastern States; some were liberated near Tarrytown, N. Y., about thirty-five years ago; 78 were turned out on Jekyl Island, near Brunswick, Ga., in 1887, and these increased to 850 during the following year;[3] others were introduced into New Jersey. Since 1890 there has been widespread interest in these experiments, and pheasants (mainly Mongolian) have now been introduced into at least twenty-five States and have increased rapidly through protection laws and the establishment of pheasantries for their propagation. Of the other species, little need be said. About 1881, 3 sand grouse were liberated near Portland, Oregon, and 9 farther west on the Clatsop Plains, but all promptly disappeared. An importation of Indian black partridges was made in 1891, but only 3 lived to reach their destination, at Macomb, Ill.[4] The black grouse has been liberated in Newfoundland and in Vermont and elsewhere in the Eastern United States. Recently the capercailzie has been introduced in the Adirondacks. European quail have been introduced several times,

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[1] Forest and Stream, XXXV, p. 28, 1890.
[2] Ann. Rept. Dept. Agr. for 1888, pp. 484–488.
[3] Forest and Stream, XXXI, p. 221, 1888.
[4] Ibid., XXXVII, p. 123, 1891.

and in 1879 nearly 3,000 were distributed in various places in New England and the Middle States,[1] but all disappeared after a year or two.

In Hawaii foreign birds have been introduced from both Asia and America. They include the Indian mina (*Acridotheres tristis*), the Java sparrow (*Munia oryzivora*), old world pheasants, the eastern turtle dove (*Turtur chinensis*) and two species of herons from China, the house finch (*Carpodacus mexicanus frontalis*) and California quail (*Lophortyx californicus*) from California, the rice bird, and the English sparrow.[2] Of these, the mina and the English sparrow are the most abundant, and display the same well-known traits which have given them an unenviable reputation elsewhere. The native birds comprise about a hundred species, and among those peculiar to the islands are some of very great interest, but which, unfortunately, are rare. Since the advent of the mongoose and of the introduced birds, some of the native species have been still further reduced in numbers, and apparently are in danger of extermination in the near future.

In the eagerness to acquire new birds, the risk of importing undesirable species has been overlooked, and even the lesson of the English sparrow has not been enough to impress on the general public the dangers of ill-advised acclimatization. But the acquisition of Hawaii and Puerto Rico, both suffering from the introduction of the mongoose, has given new importance to the subject of acclimatization, and has shown the necessity, not only of preventing the pests already on these islands from being brought into the United States, but also of protecting our new possessions against future experiments in the introduction of dangerous species. If we are to escape the losses which have been suffered in the Australian colonies, and especially in New Zealand, some restriction must be placed on the introduction of exotic species, as is now done in Western Australia. Attention has been called to this question, and it is to be hoped that the suggestion that such experiments be placed under the control of the Department of Agriculture will receive the approval of Congress at an early date.[3]

SUMMARY.

The history of American ornithology may be traced back to the middle of the sixteenth century, but the chief progress in the science has been made during the last hundred years. So assiduously have our birds been studied that the avifauna of few regions is better known than that of the Eastern United States. With the growth of ornithology, the economic relations of birds, and especially their relations to agriculture, have attracted more and more attention. During the last half century "economic ornithology" has become

[1] Forest and Stream, XII, p. 371, 1879.
[2] Ray, Osprey, IV, p. 1, September, 1899.
[3] Ann. Rept. Dept. Agr. for 1886, p. 258; Yearbook Dept. Agr. for 1898, p. 108.

recognized as a special branch of the science and has undergone rapid development. The relation of birds to agriculture depends mainly on the character of their food, and this is determined in several ways: (1) By field observation; (2) by experiments on birds recently captured, and, (3) by examination of stomach contents in the laboratory—the latter the most complete and satisfactory method. Thus far, about 20,000 birds' stomachs have been examined, and data are now available for determining the extent to which a hundred or more important species are useful or injurious. The English sparrow and several hawks and owls have been condemned, but only six or eight species in all have thus far been found injurious, while several birds commonly considered injurious have been shown to be beneficial.

The harvesting and commercial utilization of bird products has been marked by great waste and a reckless disregard for the future. The game markets, the egg trade, and the millinery trade have all made heavy drafts on our native birds, and have decimated some useful or conspicuous species and forced others to the verge of extinction. This is particularly noticeable in the case of the passenger pigeon, the egrets of the South, and the terns of the Atlantic coast. Attempts are now being made to place the killing and sale of game under proper restrictions; the trade in sea birds' eggs has been curtailed, and wide publicity has been given to the enormous slaughter of birds exacted by the demands of fashion. The guano trade, which resulted in the acquisition of a number of islands whose product was valued at more than $3,000,000, is now largely a thing of the past, owing chiefly to the depletion of the deposits, although the fact that better artificial fertilizers can now be had at lower rates than natural guano is also partly responsible for this result.

Legislative measures early in the century took the form of bounty acts directed toward the destruction of birds, but most of these have now been withdrawn, except in the case of the English sparrow. Protective measures, commonly known as "game laws," have multiplied, and protection is now extended not only to game birds but also to insectivorous species and in some States to birds of prey. That these efforts have not accomplished more, is mainly because the laws have lacked uniformity and have not been properly enforced, but the last decade has certainly witnessed some progress along these lines. Efforts have also been made to supplement State laws by federal legislation restricting interstate traffic in game killed in violation of State regulations, but although several bills embodying this principle have been considered by Congress none have as yet become laws.

Experiments in the introduction of foreign species have not met with unqualified success. English and Mongolian pheasants have been added to the list of game birds, and the European skylark, starling, and tree sparrow have gained a slight foothold in a few localities, but we have also acquired the English sparrow, one of the worst of feathered pests.

With the present knowledge of the economic relations of birds based on thorough scientific investigation, and with the recent experience of the effects of indiscriminate slaughter and unrestricted acclimatization, there is every reason to hope that practical questions in economic ornithology will hereafter receive more careful and intelligent consideration.

PROGRESS OF FORESTRY IN THE UNITED STATES.

By Gifford Pinchot,
Forester.

ATTITUDE OF THE PIONEERS TOWARD THE FOREST.

The sentiment for forest protection was strong among the early settlers of the United States. In Massachusetts repeated enactments provided for the care and protection of the forests adjacent to the various communities. In New Jersey laws against forest fires took their places very early upon the statute books. In Pennsylvania the founder of the Commonwealth made it a condition that, of all land acquired from him, 1 acre of forest should be left standing for every 5 acres cleared. This conspicuous care for the forest in regions where at first it was a hindrance rather than a help to the gaining of a livelihood is explained by the early associations of the settlers. They came from a country where wood was comparatively scarce, and where the penalties for its destruction were severe and severely enforced. The respect for the forest which had been bred in their ancestors by the early English game laws, and continued in themselves by enactments of extreme rigor, was brought over almost without change to their new land, but it was not destined to last. A growing realization of the vast resources at their command, together with the bitter struggle of the farmer against the forest in the early days, gradually replaced care with carelessness, and respect with a desire for destruction. The feeling bred by the battle against the forest began to take a dominant place in the minds of the people and to prepare that mental attitude which is still responsible for the greater part of the forest destruction even yet in almost undiminished progress over by far the larger part of the United States.

EARLY PROTEST AND ACTION AGAINST FOREST DESTRUCTION.

Following the spread of forest destruction came protest and action against it. In the last decade of the eighteenth century the New York Society for the Promotion of Agriculture, Arts, and Manufactures, and in the first years of the nineteenth, the Massachusetts Society for the Promotion of Agriculture, took action, inspired by a desire to protect and promote the growth of forests. In 1799 Congress passed an act for the purchase of timber suitable for the use of the Navy, or of land on which such timber was growing. This law, reenacted in 1817 and supplemented in 1820, 1822, 1827, 1828, and 1831, led to the purchase and partial protection of 244,000 acres of forest-bearing land in Florida, Alabama, Mississippi, and Louisiana, and, in Florida, to some partially successful efforts at the culture of the live oak.

DEVELOPMENT OF A FOREST POLICY.

Immediately following the civil war came a development of rail-road building without parallel in the history of the world, and with it a coincident extension of the lumber trade and of forest destruction. Agitation followed it feebly and at a distance, but not without planting the seed from which the present agencies for forest protection have sprung. In 1867 horticultural and agricultural societies in Wisconsin appointed a committee to report on the results of forest destruction, and two years later the Board of Agriculture of Maine took action toward the formulation of a forest policy for the State. Laws for the encouragement of tree planting were passed between 1868 and 1874 in nine Western and two Eastern States, and in 1873, 1874, 1876, and 1878 Congress passed and amended the timber-culture acts, which provided for the granting of homesteads to settlers who planted one-fourth of their entries with certain specified kinds of trees. The very mediocre results of these measures led to their repeal in 1891.

In 1831, under the act of that year, a partial oversight and protection of the public timber lands was assumed by the Solicitor of the Treasury, acting through the regular agents of the Department. This function was transferred in 1855 to the General Land Office, in the Department of the Interior, where it has since resided. Under this system cases of deliberate trespass were settled by payment of the stumpage value of the timber unlawfully taken, while cases of unintentional trespass were satisfied by actual entry, with the payment of customary entry fees. Express appropriation for the pay of special timber agents was not made until 1872, when $5,000 was appropriated, and this amount was continued annually thereafter until 1878. The ineffectual working of the system was recognized in that year by an appropriation of $25,000 to meet the expenses of suppressing depredations. Appropriations for this purpose were afterward increased to a maximum of $120,000 in 1893.

The same act which repealed the timber-culture laws contained a clause, whose insertion was due largely to the efforts of members of the American Forestry Association, by which the President was authorized to set aside "any part of the public lands wholly or in part covered with timber or undergrowth, whether of commercial value or not, as public reservations, and the President shall, by public proclamation, declare the establishment of such reservations and the limits thereof." Under the provisions of this clause, which may fairly be described as the first marked step toward a national system of forestry, the reservations shown in fig. 4 were set aside. The existence of some 18,000,000 acres of forest reserves, wholly without care or management by the Government, was perhaps the primary cause which led the Secretary of the Interior, in February, 1896, to address to the president of the National Academy of Sciences a request for an investigation and report upon the "inauguration of a rational forest policy for the forested lands of the United States," and upon the questions which underlie it. In reply, Dr. Wolcott Gibbs recited the difficulties of the undertaking and the best means of surmounting them, and expressed his willingness to comply with the Secretary's request.

The result of this correspondence was, on the part of the academy, the appointment of a committee of seven, of whom six were chosen from among its most distinguished and experienced members, the seventh being a professional forester, and on the part of the Government, the appropriation of $25,000 to defray the committee's traveling and other expenses. All its members served without pay. After a summer spent in active examination of forest reserves, proposed and established, on the ground, the committee recommended as a preliminary step the segregation of eleven new reserves with a total area of somewhat more than 21,000,000 acres. These reserves were established by the President on February 22, 1897. The wording of the proclamation led many persons to believe that the lands reserved were to be wholly withdrawn from every sort of use and development, a belief carefully fostered by some who, for reasons of their own, were opposed to the reserves. No pains were taken to enlighten the public upon this point until the harm had been done. The report of the committee, whose appearance would have done much to set matters straight, was not submitted until May 1 of the same year. Vigorous and even violent attacks upon the President and upon the committee and its members became frequent in Congress and culminated, after a spirited fight, in a provision of law which suspended the action of the proclamation of the new reserves, except in the State of California, until March 1 of the succeeding year (1898). In the meantime public sentiment concerning the reserves underwent a remarkable change. A better understanding of their objects and a knowledge of the new law (act of June 4, 1897), which regulated their use in practical accord with the principal recommendations of the committee, spread throughout the West. A further official study of the reserves, while it suggested certain modifications of their boundaries, served to confirm their desirability as a whole, and an attempt to continue the suspension beyond March 1 failed completely. Instead, the estimate of the Secretary of the Interior for their care and preservation was more than doubled by the appropriation of $175,000 in Congress for that purpose, and shortly after President McKinley proceeded to establish further

FIG. 4.—Forest reserves and national parks: 1 and 2, Yellowstone Park Timber Land Reserve, Wyoming, 1,239,040 acres; 3, White River Plateau Timber Land Reserve, Colorado, 1,198,080 acres; 4 and 35, Pecos River Forest Reserve, New Mexico, 431,040 acres; 5 and 6, Pikes Peak Timber Land Reserve, Colorado, 184,320 acres, 7, Bull Run Timber Land Reserve, Oregon, 142,080 acres; 8, Plum Creek Timber Land Reserve, Colorado, 179,200 acres; 9, South Platte Forest Reserve, Colorado, 683,520 acres; 10, San Gabriel Timber Land Reserve, California, 555,520 acres; 11, Battlement Mesa Forest Reserve, Colorado, 858,240 acres; 12, Afognak Forest and Fish-Culture Reserve, Alaska, 403,640 acres; 13, Sierra Forest Reserve, California, 4,096,000 acres; 15, Grand Canyon Forest Reserve, Arizona, 1,851,520 acres; 16, San Bernardino Forest Reserve, California, 737,280 acres; 17 and 40, Trabuco Canyon Forest Reserve, California, 109,920 acres; 18, Cascade Range Forest Reservé, Oregon, 4,492,800 acres; 19, Ashland Forest Reserve, Oregon, 18,560 acres; 20, Stanislaus Forest Reserve, California, 691,200 acres; 21, San Jacinto Forest Reserve, California, 737,280 acres; 22, Bitter Root Forest Reserve, Idaho and Montana, 4,147,200 acres; 23, Priest River Forest Reserve, Idaho and Washington, 645,120 acres; 24 and 39, Black Hills Forest Reserve, South Dakota, 1,211,680 acres; 25, Uintah Forest Reserve, Utah, 875,520 acres; 26, Washington Forest Reserve, Washington, 3,594,240 acres; 27, Olympic Forest Reserve, Washington, 2,188,800 acres; 14, 28, and 44, Mount Rainier Forest Reserve, Washington, 2,027,520 acres; 29, Big Horn Forest Reserve, Wyoming, 1,127,680 acres; 30, Teton Forest Reserve, Wyoming, 829,440 acres; 31, Flathead Forest Reserve, Montana, 1,382,400 acres; 32, Lewis and Clarke Forest Reserve, Montana, 2,926,080 acres; 33 and 36, Pine Mountain and Zaca Lake Forest Reserve, California, 1,644,594 acres; 34 and 47, Prescott Forest Reserve, Arizona, 423,680 acres; 37, San Francisco Mountains Forest Reserves, Arizona, 975,360 acres; 38, Black Mesa Forest Reserve, Arizona, 1,658,880 acres; 41, Fish Lake Forest Reserve, Utah, 67,840 acres; 42, Gallatin Forest Reserves, Montana, 40,320 acres; 43, Gila River Forest Reserve, New Mexico, 2,327,040 acres; 45, Lake Tahoe Forest Reserve, California, 136,335 acres; 46, Santa Ynez Forest Reserve, California, 145,000 acres. Total, 46,983,969 acres. The numbers on the map refer to proclamations creating or modifying reserves; hence, some of the reserves have more than one number.

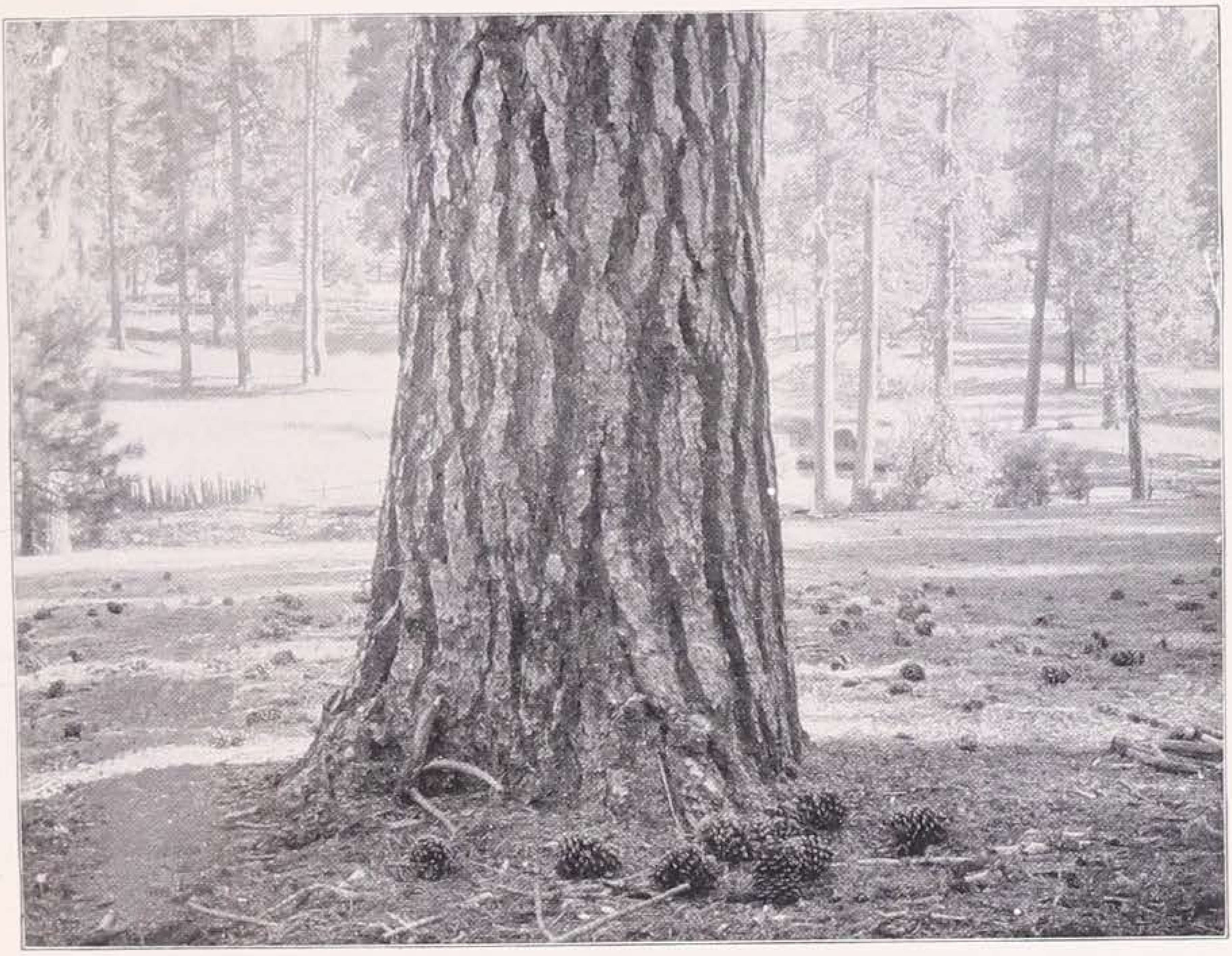

FIG. 1.—TYPICAL FOREST IN STANISLAUS FOREST RESERVE, CALIFORNIA. PREVAILING SPECIES JEFFREY PINE, WITH A FEW WHITE FIR AND INCENSE CEDAR.

FIG. 2.—GENERAL FOREST VIEW IN STANISLAUS FOREST RESERVE, CALIFORNIA. OPEN FOREST OF YELLOW PINE, MIXED WITH WHITE FIR, SUGAR PINE, AND INCENSE CEDAR.

reserves. The area of all the reserves established by him up to January 1, 1900, is 6,708,425 acres.

The work of the committee of the National Academy of Sciences, while it failed of much that it might have accomplished, nevertheless was the spring from which the present activity in forest matters was derived. The proclamation of the reserves which it recommended drew the attention of the country as nothing else had ever done to the question of forestry. Vigorous discussion of forest matters by the public press led to a widespread interest, and that in turn to a keen appreciation of the value of forests in the economy of each State, and to a willingness to take measures to protect them. It may fairly be assumed that, as one of the results of this awakened interest, the policy of making Government forest reserves is now established beyond the reach of further question. (Pl. IX.)

ADMINISTRATION OF THE NATIONAL FOREST WORK.

One of the consequences of the controversy which ended in the retention of the reserves was the division of the responsibility for them between two bureaus of the Department of the Interior, and the consequent separation of the forest work of the Government into three unrelated parts. As the matter now stands, the General Land Office is charged with the administration and protection of the reserves, the United States Geological Survey maps and describes them, and the Division of Forestry of the Department of Agriculture, in which are all the trained foresters in the Government service, has no relation whatever to this most important branch of the Government's forest work, except as the officers of the Department of the Interior may incidentally apply for assistance or advice. The connection of the United States Geological Survey with the forest reserves is obviously a temporary one, which will cease when the work of mapping and description is at an end; but the complete separation between the administration of the reserves in the General Land Office and the force of trained foresters specially equipped for that purpose in the Division of Forestry constitutes what is perhaps the most serious defect in the present organization of the federal forest work.

The force employed for the care and protection of the forest reserves under the General Land Office consists of 9 superintendents, 39 supervisors, and a number of forest rangers, which in summer attains 350, but which varies with the seasons and the danger from fire. Protection against fire, the foremost enemy of forests in America, is the most pressing and important duty which devolves upon this force. The law of June 4, 1897, from which the Secretary of the Interior derives his powers concerning the reserves, confers upon him, and through him upon the Commissioner of the General Land Office, every necessary authority and power for their management by whatever methods he may deem best. Legally there is no obstacle to the intr duction of the most practical and approved ways of handling fore lands.

NATIONAL PARKS.

While the national parks, speaking strictly, do not at present for a part of the forest system of the United States, still, since one their prime objects is the protection of the forests within their boun aries, they fall naturally within the sphere of the present pape They differ from forest reserves chiefly in the fact that no lumberi can be carried on within them, that the mining laws, except in t case of the Mount Rainier National Park, do not apply to them, th their game animals are fully protected, and that they are under t care of the troops of the Regular Army, assigned to that duty by t Secretary of War, but under the orders, for that purpose, of the Secr tary of the Interior, and reporting to him.

The best known and the largest of the national parks is the Ye lowstone, with an area of 2,142,720 acres, located in Wyoming, wit small portions in Montana and Idaho. The others are the Yosemi National Park (967,680 acres), the Sequoia National Park (161,28 acres), and the General Grant National Park (2,560 acres), all in Cal fornia, and the Mount Rainier National Park (207,360 acres) i Washington.

PRIVATE FORESTRY.

The development of practical forestry in the United States has pro ceeded until recently along three principal lines—private, State, an national. Contrary to the general rule in other countries, practica forestry here began first on private lands and wholly without relatio to governmental action. Apart from the attempts of lumbermen i the Eastern spruce regions, many of which were successful, to cu their timber so as to get a second crop, the first instance of systemati forest management in the United States occurred on the land of Mr George W. Vanderbilt at Biltmore, N. C., beginning in 1892. (Pl X.) From that time, although the work at Biltmore still continued steadily and successfully, until the middle of 1898 the application o forestry to large private tracts made little progress. Since then, unde the impetus of an offer of advice and assistance from the Division o Forestry, private owners have taken the matter under advisement i considerable numbers, and practical work has already been unde way, at the present writing, on considerable areas for more than a year. On January 1, 1900, the total area for the management of which assistance had been asked of the Division of Forestry was more than 2,000,000 acres. Lumber companies and forest-owning associations as well as individuals are directing their attention with increasing seriousness and frequency toward practical forestry.

CONSERVATIVE LUMBERING. A LARGE OAK CUT AND WORKED UP INTO CORD WOOD WITHOUT INJURY TO THE SAPLINGS ABOUT IT. BILTMORE, N. C.

While private forestry has thus been making noteworthy and rapidly accelerating progress in the recent past, practical forestry on Government land during the same period has not advanced beyond the incipient stages of forest protection. Nor are any of the States more advanced.

STATE FORESTRY.

Practical forestry has not yet been introduced on any State forest land, and even New York, which owns about 1,250,000 acres in the Adirondack and the Catskill mountains, has not yet progressed beyond the stage of simple protection. To have reached this, however, is a long stride in advance. The constitution of New York forbids the cutting, destruction, or removal of any tree on the "forest preserve," as the lands definitely assigned to forest uses held by the State are collectively called, a provision which is quite as effectively opposed to practical forestry as it is to forest destruction, and which must be regarded as purely temporary in character. The forests of the State, as well as its salt-water and fresh-water fisheries and its game animals and birds, are under the care of a commission of fisheries, game, and forests appointed by the governor, having under it a superintendent and a corps of subordinates in the woods. The sincere interest of the people of New York in the forest preserve is indicated by the recent appropriation and expenditure of $1,800,000 to increase the area of the preserve by purchase.

In Pennsylvania the acquisition of wild lands by the State for forest uses has become an established policy, and bids fair to result in the control and management of an area not greatly inferior to the forest preserve of New York; and Pennsylvania has no legal bar to practical forestry. Michigan has recently taken steps in the same direction, and several other States have taken or seem about to take similar action. It may be said of the forested States in general that public sentiment is moving rapidly toward a satisfactory treatment of the question of State forest lands.

The following is a list of States which exercise control of forest matters, with the respective authorities through which such control is exercised in each:

CALIFORNIA.—University of California. A State board of forestry was created in 1885, but was abolished in 1892, its experimental groves passing under the present control.

COLORADO.—Fish and game commissioner. A commissioner of forests was created in 1885. This office lasted for six years. Appropriations never more than $2,000.

KANSAS.—State forest commissioner since 1887.

MAINE.—State auditor, ex-officio forest commissioner, since 1891. This officer, though greatly restricted by the smallness of his annual appropriation of $400, exerts important influence through his published reports and by his administrative work in carrying into effect the excellent fire law of the State.

MASSACHUSETTS.—The State board of agriculture, which acts also as a board of forestry.

MICHIGAN.—Permanent commission of three members, serving without pay, but receiving traveling and other official expenses, was created in 1899.

MINNESOTA.—State forestry board, created 1899, cooperating with town and county boards, and consisting of nine members.

NEW HAMPSHIRE.—Forest commission, established in 1893. This is the outcome of two preliminary commissions of investigation, the first of which was appointed in 1885 and lasted four years, and the second, appointed in 1889, lasted two years. It consists of the State governor, ex officio, and four other members.

NEW JERSEY.—State geologist. No independent forest officer.

NEW YORK.—Fisheries, game, and forest commission. There have been three commissions. The first was created in 1885, and was known as the "State forest commission." It was remodeled in 1893, the number of its members being increased from three to five. In 1895 the forest commission and the fish and game commission were consolidated under the present title.

NORTH CAROLINA.—State geological survey. No independent forest officer.

NORTH DAKOTA.—Superintendent of irrigation and forestry since 1891.

OHIO.—State forestry bureau was created in 1885.

PENNSYLVANIA.—Commissioner of forestry, appointed in 1893. On the creation of the State department of agriculture in 1895 a division of forestry was provided for, of which the forest commissioner became chief.

FOREST-FIRE LEGISLATION.

The legislation enacted by the various States with the object of preventing damage from forest fires is, on the whole, of a very satisfactory character. The main difficulty lies in the unwillingness or inability of the authorities in the various States to enforce the laws as they stand. Legislation is in most cases in advance of public opinion, but the latter is making very rapid progress. Among the best forest-fire laws are those of Maine, New Hampshire, Minnesota, New York, Pennsylvania, and Wisconsin.

The provisions of the New York law direct the appointment by the fisheries, game, and forest commission of a firewarden in each town in the counties comprising the forest preserve. Where special liability to injury from fire exists, the firewardens are required to divide their towns into two or more districts and to appoint one district firewarden for each. On the outbreak of a forest fire firewardens are directed to summon persons to assist in putting out or checking the fire, and no action which they may take to this end shall constitute a trespass. The firewardens and their assistants receive a fitting compensation for the time actually employed at the fire, the expenses being borne half by the town and half by the State. In towns not within the counties comprising the forest preserve supervisors of towns are made ex-officio firewardens. In addition to these safeguards the law makes it a misdemeanor to fire woods or waste lands belonging to the State or to another, whether willfully or negligently, if such fire results in

FIG. 1.—THE EFFECTS OF FIRE AFTER LUMBERING IN NORTHERN MINNESOTA.

FIG. 2.—FOREST LAND IN MINNESOTA DEVASTATED BY FIRE.

injury to woodland, and punishes the offender by a fine not exceeding $250 or imprisonment not exceeding one year, or both, besides awarding damages to the person injured.

The Minnesota law is very similar in general effect, but there is rather more central authority. The pay of the county wardens is not left to the counties, though not a dollar can be paid them without the approval of the county commissioners. The pay is limited to $2 per day, but can not exceed $15 a year. The chief firewarden, who has administrative control of all matters pertaining to the extinguishment of fires, secures the services of settlers to act as wardens in the unorganized territory. Minnesota has this advantage: That her forest-fire officials receive their pay more promptly than elsewhere, and thus take a more live interest in the performance of their duties. Pl. XI shows effects of fire in Minnesota.

THE DIVISION OF FORESTRY.

In 1873 a committee of the American Association for the Advancement of Science was appointed "to memorialize Congress and the several State legislatures upon the importance of promoting the cultivation of timber and the preservation of forests, and to recommend proper legislation for securing these objects." This action was followed by the appointment, in 1876, of Dr. Franklin B. Hough, of Lowville, N. Y., who may be considered historically, although not literally, as the first chief of the present Division of Forestry of the Department of Agriculture. Dr. Hough's duties were "to ascertain the annual amount of consumption, importation, and exportation of timber and other forest products, the probable supply for future wants, the means best adapted to the preservation and renewal of forests, the influence of forests on climate, and the measures that have been successfully applied in foreign countries or that may be deemed applicable in this country for the preservation and restoration or planting of forests, and to report upon the same to the Commissioner of Agriculture, to be by him in a separate report transmitted to Congress." In 1883 Dr. Hough was succeeded by Mr. N. H. Egleston, who in turn was followed, in 1886, by Mr. B. E. Fernow, who continued to direct the work of the Division until July 1, 1898.

At first and until recently purely a bureau of information, the Division of Forestry has become within the last eighteen months an active participant in practical forest work in the woods throughout the United States. Among the three federal organizations concerned with forest work (see page 297), the Division of Forestry is alone responsible for the progress of the science and art of forestry and for the vast interests which are involved in the spread of conservative forestry over the enormous private holdings of forest land in the United States. Its work has recently been reorganized throughout. This reorganization, together with the fact that the position and practice of the Division are largely typical of the present attitude of the Government toward forestry, makes requisite a somewhat extended description of its work.

The work of the Division is now chiefly in the field. Its office work is organized on a scale sufficient to support the field work and secure its best results, but the principal scene of its activities is in the woods. At present all the work of the Division is assigned to four sections, each with a man of special knowledge and qualifications at its head. These are the sections of working plans, of economic tree planting, of special investigations, and of office work. The following extract from the Annual Report of the Secretary of Agriculture for the year ending June 30, 1899, describes in sufficient detail the lines along which the work of the Division is now organized. The total appropriation for the year named was $28,520.

PRACTICAL ASSISTANCE TO FARMERS, LUMBERMEN, AND OTHERS.

Last October a circular was issued (No. 21 of the Division of Forestry) offering advice and practical assistance to farmers, lumbermen, and others in handling their forest lands, with a view to bringing about the substitution of conservative for destructive methods. This offer provided for the preparation of working plans, with full directions for work and with practical assistance on the ground, without cost to the owners of wood lots, but in the case of larger tracts requiring the owners to meet expenses for travel and subsistence, and for the necessary helpers for the agents of the Division while in the field.

During the year applications were received from 123 owners in 35 States for the management of 1,513,592 acres. Of these applications, 48 were for large tracts covering together 1,506,215 acres, the remainder being for wood lots.

Personal attention on the ground was given to 41 tracts, covering about 400,000 acres in 19 States. The contribution of private owners to the expenses of this work was about $3,000.

It was found possible for the owners of a majority of these tracts to carry out the working plans without personal assistance, but 15 of them required the active participation of the Division. On two of the latter, comprising 108,000 acres, the working plans were put into execution early in the year, and the first year's work has been successfully completed. The second year's work is being pursued under very favorable conditions.

As a result of a calculation, based on exact measurements, of the amount of lumber wasted by the prevailing practice of cutting high spruce stumps in the Adirondacks, there has been a decided change for the better on certain tracts, and at the same time a great reduction in the amount of young spruce cut for road building has been brought about. These are important changes.

In connection with the preparation of the working plans for the two large tracts in the Adirondacks, a special study has been made of the growth and production of the spruce on the eastern side of the mountains and of birch and maple on the western slope.

Of the total amount of land submitted for working plans, about 1,200,000 acres have not yet been examined. These tracts will be considered during the ensuing year as fast as the very inadequate force of the Division will permit, and working plans will be made for a selected number.

The Division has been thoroughly equipped with instruments for field work, in which it was wholly lacking at the beginning of the year.

COMMERCIAL TREES.

During the year five species of commercially valuable trees have been studied to determine their rate of growth and to ascertain their special qualities in forestry. The more important of these studies relate to the loblolly pine in North Carolina, a tree of the first economic importance, and the red fir in Washington, also called Douglas fir, yellow fir, Oregon pine, etc., one of the most valuable and widely distributed trees of the world. These studies have met with the cordial approval of lumbermen, and much practical assistance has been rendered by them. In addition, the study of the coast redwood in California has recently been begun, and later, if enough money can be saved for that purpose, the white oak and the hickories will be taken up.

ECONOMIC TREE PLANTING.

The planting of experimental plats in cooperation with State agricultural experiment stations has been discontinued, and the stations have taken over the plantations and assumed the responsibility for them. This was done after a thorough study of the old plan, after careful examination of the plantations at nine of the eleven stations, and with the acquiescence of the authorities of every station. Two other lines of work have taken the place of experimental tree planting. One is a careful study of the results of the planting already done, in which all the species used in the cooperative plantations are represented, and from which practically all the results to be expected from them after many years may be gathered without delay and far more cheaply; and the other the giving of practical assistance to tree planters under the terms of an offer (set forth in Circular No. 22, Division of Forestry) similar to that made to forest owners.

Close relations have been established with five of the most competent men in the treeless regions, and these gentlemen are preparing reports on subjects of direct interest to tree planters.

In addition to the studies now being pursued, the work of the present year will in great measure be devoted, first, to giving practical assistance to tree planters in the selection of the proper trees to plant and in planting them rightly, and, secondly, to an attempt to determine the true effect of bare and wooded or brush-covered slopes on the run-off of streams. The vast interests affected by the solution of this difficult problem will justify the most persistent and careful work.

SPECIAL INVESTIGATIONS.

Forest fires have been studied historically and in the field, and important results have been reached. Records of more than 5,000 fires have been compiled and classified, and field work has been prosecuted in seven States.

A series of studies of North American forests by experts with special knowledge of definite localities is in progress, and it is expected that three of them will be completed during the coming winter.

Historical studies of the progress in forestry in New Jersey, Massachusetts, and other States have been begun, and those for New York are practically completed.

Much material has been collected for a general account of the progress of forestry in the United States and of the practical application of conservative forest treatment in this country up to the present time.

Noteworthy progress has been made during the year in the photographic forest description of the United States.

OFFICE WORK.

The mailing list has been revised and extended, especially among newspapers, and much material for publication has accumulated and awaits attention during the winter. The botanical work formerly carried on by this Division has been turned over to the Division of Botany, where it more properly belongs.

During the year the force has been much increased, largely by the addition of young American foresters. At its highest, the total membership was more than five times that at the beginning of the last fiscal year.

Through a system of cooperation with experts in forest matters throughout the United States, the Division of Forestry is becoming in fact what it has long been in intention, the center of all forest activity in the United States, while through the appointment of student assistants it is gathering about its work a corps of young men, who, beginning their forest studies while actively engaged in the work of the Division, principally in the field, will complete them at one or another of the forest schools. In this way, as well as through the schools alone, the need for men, which is among the most pressing requirements of forestry in the United States at present, will gradually be met.

TREE PLANTING.

Tree planting in the treeless West is a legitimate and exceedingly important branch of forestry in the United States. The successful cultivation of farm crops in many portions of this country is dependent upon the protection derived from successful tree planting, and over a very large part of the agricultural West both the comfort of the farmer and his prosperity are deeply concerned with it. Tree planting has been in active progress for more than thirty years over considerable portions of the West, and a large amount of information has been collected as to the value for planting of a large number of trees. (Pl. XII.) This information has not been collated and is not available in any compact form. On account of the vastness of the interests involved, this is one of the most important pieces of forest work to be done.

ASSOCIATIONS.

The progress of associated effort for the protection of forests, slow at first, has of late years become very rapid. There are now some 22 associations in the United States which deal directly with forest matters. Of these the pioneer, if we disregard those which have not survived, and in many ways the most influential, is the American Forestry Association, founded at Cincinnati in 1882, under the name of the American Forestry Congress. This association, while less in number of members than the Pennsylvania Forestry Association, has done and is still doing work of the first importance toward the spread of right ideas about forestry, chiefly through its monthly organ, The Forester. The Pennsylvania association, founded in June, 1886, has been instrumental in placing the State for which it is named in the first rank of forest progress. It publishes a bimonthly journal entitled Forest Leaves. Among the other prominent organizations

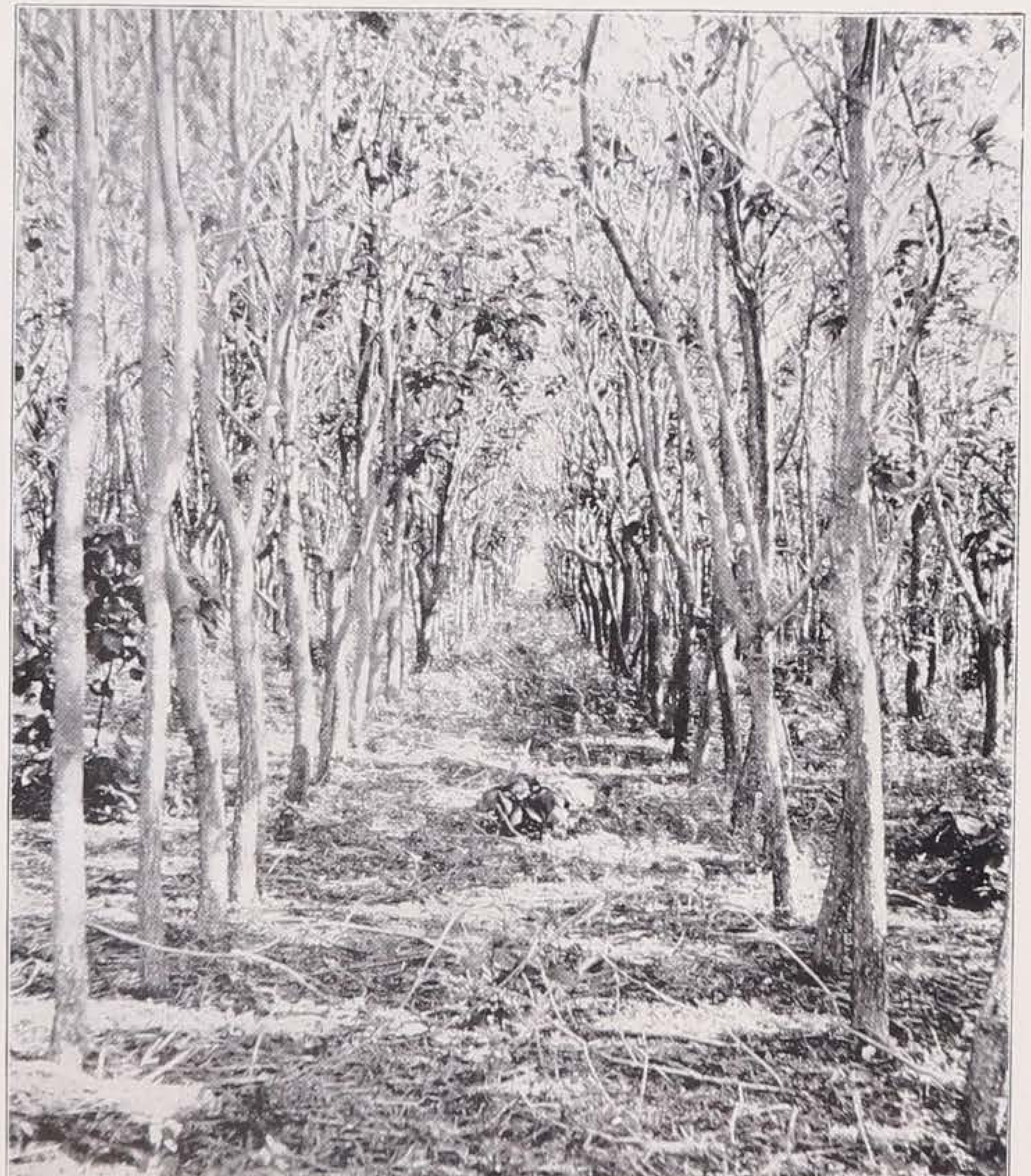

Fig. 1.—Catalpa Plantation, Twelve Years Old. Riley County, Kans. A few Young Oaks are Growing between the Rows of Catalpa.

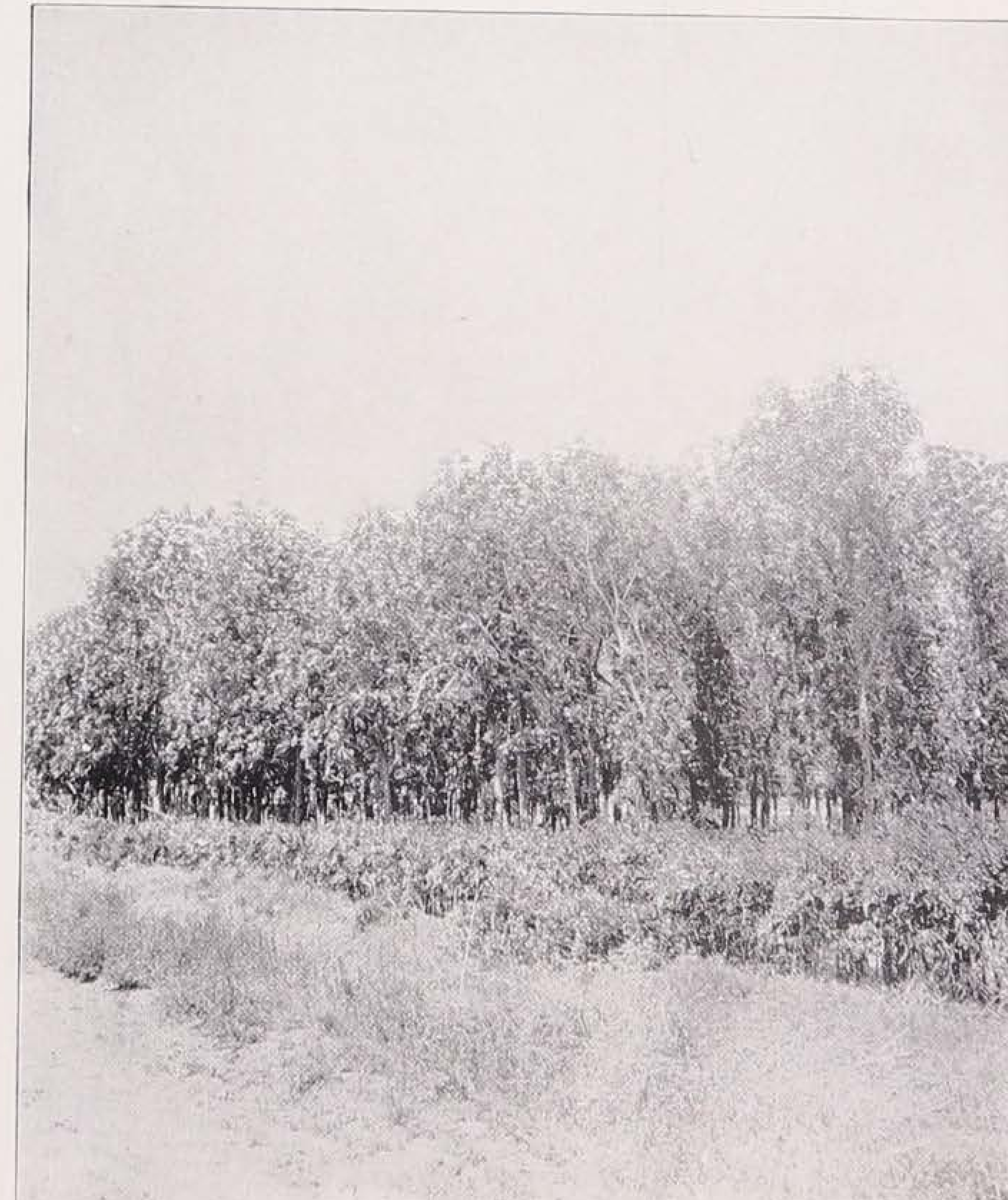

Fig. 2.—Grove of Black Walnut, Thirty-one Years Old. Riley County, Kans.

which have weight in forest matters are the Sierra Club and the Water and Forest Society of California, the Massachusetts, Wisconsin, Minnesota, and Colorado forest associations, and the Mazamas, of Oregon.[1]

INSTRUCTION IN FORESTRY.

Except in the case of the student assistants mentioned on page 304, the Government of the United States takes no part in the education of foresters. Elementary instruction in forestry has, however, already received noteworthy extension in the State agricultural colleges and to some degree in other institutions. Thirty-two of the former, according to the best information available, now offer instruction in forestry, either as a separate subject or in connection with courses in agriculture, horticulture, or botany. Among these institutions the college of agriculture of the University of Minnesota deserves special mention, both from the value of the forest courses it offers and because of its priority in the field.

The most elaborate and extensive institution in this country for the training of foresters is the New York State College of Forestry, organized in 1898 as a part of Cornell University. Modeled upon German lines, it offers a four years' course leading to a degree. Thirty thousand acres of forest in the Adirondack Mountains, controlled by the school, furnish an abundant field for practical operations. The Biltmore Forest School, also begun in 1898, is situated in Biltmore Forest, on the Vanderbilt estate, near Asheville, N. C., and offers a happy combination of practical and theoretical instruction. These, with Berea College, at Berea, Ky., which offers a year's work in forestry, and the University of Minnesota, are the principal agencies for the education of professional foresters.[1]

Steps have been taken which will result in the opening of a forest school as a department of Yale University in the autumn of 1900.

PROTECTION OF FISH AND GAME.

The protection of fish and game is less intimately associated with forest matters in the United States than in many other countries. Salt-water fisheries, which, because of the great length of coast line, produce so very large a portion of the total food product derived from the water, naturally have little connection with forests. As regards the fresh-water fishes and the game, separation between these two sets of interests and the forest has worked to the disadvantage of the latter. Hitherto it has been much easier to secure legislation for the protection of fish and game than for the protection of forests. In the future, however, as the various States produce or perfect their machinery for the right handling of forest lands, a much closer connection

[1] A full list of States which have forest associations; also a list of the universities and colleges in which instruction in forestry is given, will be found in the Appendix to this Yearbook.—Ed.

may be expected, in which it is most probable that all the interests will find their profit. The protection of fish and game is a natural function of the forest guard.

ARBOR DAY.

Prominent among agencies for interesting the children in forest matters is the observance of Arbor Day. Instituted in Nebraska in 1872 by Hon. J. Sterling Morton, Secretary of Agriculture 1893–1897, Arbor Day has made its way from State to State until, at the beginning of 1900, provision for its observance has been made in every State and Territory. Its central idea is the planting of trees by school children on dates fixed by proclamations of the governors of the various States or by other authorities. The planting is usually accompanied by exercises, often of considerable elaboration, intended to impress upon the children the beauty and usefulness of trees, and to encourage the care and preservation alike of shade trees and forests. While the planting accomplished may have in itself little economic value, the institution of Arbor Day may fairly be said to exercise immense influence in exciting affection and respect for trees in the coming generations, and so to prepare a body of sentiment which will assist powerfully hereafter to bring about the general practice of conservative forestry.

PROGRESS OF AGRICULTURE IN THE UNITED STATES.

By George K. Holmes,
Assistant Statistician.

CRUDE BEGINNINGS BY INDIANS.

Indians carried on agriculture in a primitive and very limited way in the region now embraced in the United States before the country was inhabited by the white race, and to their crude agriculture they joined the harvesting of the wild products of nature.

SOME CROPS AND METHODS OF CULTIVATING AND GATHERING.

Indian corn.—The farming practiced on the eastern side of North America by the Indians was to burn off the forest, scrape up the top soil into little hills, and, if corn was to be raised, to plant the seed therein. Indian corn, or maize, was indigenous, and the Indians raised it from time immemorial. Women did the work, and the only implements employed were their fingers, a pointed stick for planting, and a clam shell or the scapula of an animal for a hoe. At the time of harvest the ears of corn were stored in a cache, or were hung up to dry, held together by the braided husks.

Tobacco.—Tobacco was another plant indigenous to America, and the Indians, who had learned its narcotic property, were in the habit of smoking the leaves after they had been dried.

Food and textile plants.—The Indians of northern California gathered the seeds of wild plants and roasted them on hot stones, to be ground afterwards into coarse flour by a stone operated in a hollow in a rock. Mojave Indian women planted gourd seeds in the crevices of rocks, and when the gourds were ripe gathered enormous quantities of them. Especially along the whole western coast of North America, Indian women gathered wild hemp, agave, and other textile plants; they dried the leaves or stalks, macerated them in water, extracted the fiber, and spun it on their naked bodies without the use of any implement whatever, and then made fabrics for domestic use.

Wild rice.—Throughout the Great Lake country the Indian women beat the heads of the wild rice plants while holding them over their canoes; having fanned the chaff away by using a large tray, they ground the rice in a mortar and cooked it in much the same way as corn.

WILD CHERRIES AND ROOTS.—The Sioux Indians beat dried wild cherries with buffalo meat to form their winter stock of pemmican. In Oregon and Washington an immense amount of food was gathered from the camass root, and also from the kouse root.

FRUITS, NUTS, ETC.—The Indians gathered the indigenous strawberries, huckleberries, blackberries, raspberries, cranberries, etc., and the chestnuts, butternuts, hickory nuts, walnuts, hazelnuts, and beechnuts. They lived also upon fish and the flesh of deer, bear, buffalo, and other wild animals, both fresh and dried.

BEGINNINGS OF AGRICULTURE BY THE WHITE RACE.

Next the white man came. Poor in the materials of wealth, indeed almost destitute of them, a stranger in a strange land with a strange climate, and beset by native enemies, the white settler had in prospect a simple subsistence upon a few products of a crude agriculture and an insignificant dairy, with such fabrics and other products as might be obtained from a primitive domestic industry. He saw the golden ears of maize strung up in the wigwams of the Indians and learned its value as food; he learned how to plant it, and also the value of putting fish for fertilizer under the seeds.

EARLY COLONIAL CONDITIONS.

Typical references to early colonial conditions are selected from Professor McMaster's "History of the people of the United States;" from Mr. Weeden's "Economic and social history of New England," and from Professor Bruce's "Economic history of Virginia in the seventeenth century."

In Georgia in 1790 the staple was tobacco, cultivated in the simplest manner, with the rudest of tools. Agriculture as we now know it can scarcely be considered to have existed. The plow was little used. The hoe was the implement of industry; made at the plantation smithy, the blade was ill formed and clumsy, and the handle was a sapling with the bark left on. After a succession of crops had exhausted the soil the cows were sometimes penned upon it.

In Virginia the poor whites, who had formerly been indentured servants, were the most lazy, the most idle, the most shiftless, and the most worthless of men. Their huts were scarcely better than negro cabins; the chimneys were of logs, the chinks being filled with clay. The walls had no plaster, the windows had no glass, and the furniture was such as they themselves made. Their grain was thrashed by driving horses over it in the open field; when they ground it, they used a rude pestle and mortar, or placed it in the hollow of one stone and beat it with another.

Each family in New England lived in a state of almost entire independence of other families and of all other communities than the one in which it lived. Beef or pork, generally salted, salt fish, dried apples, bread made of rye or indian meal, milk, and a very limited variety of vegetables constituted the food throughout the year. The Massachusetts farmer who witnessed the Revolution plowed his ground with a wooden plow, sowed his grain broadcast by hand, and when it was ripe cut it with the scythe and thrashed it on the barn floor with a flail. His house was not painted; his floor was not carpeted. When darkness came on his light was derived from a few candles of home manufacture. The place of furnaces and stoves was supplied by huge cavernous fireplaces which took up one side of the room and, sending half the smoke into the apartment, sent half the heat up the chimney. The farmer and his family wore homespun. If linen was wanted, the flax was sown and weeded, pulled and retted, and broken and swingled, for all of which processes nearly a year was required before the flax was ready for spinning, bleaching on the grass, and making and wearing. If woolens were wanted, sheep were sheared and the wool was dyed and spun and woven at home.

It was almost invariably true of all the settlers that the use and value of manures was little regarded. The barn was sometimes removed to get it out of the way of heaps of manure, because the owner would not go to the expense of removing these accumulations and putting them upon his fields.

In comparison with present conditions, the farmer's life in colonial days was a dreary one, filled with hardships and deprivations, and treading very closely upon the margin of subsistence. Those conditions continued after the Republic had been established, and were not measurably ameliorated until the present century had well advanced—until an improved intelligence, the dissemination of information, and especially the work of the inventor had begun to take effect.

FIRST CROPS.[1]

CEREALS.—The first yield of indian corn, or maize, in any considerable quantity produced in the United States by people of English blood of which we have any authentic record was that of 40 acres in the Jamestown Colony in 1609.[2] Wheat was first sown in Massachusetts on the southern coast as early as 1602, and it was first cultivated in Virginia in 1611. Rye dates back in New England certainly to 1648, and perhaps to 1630, and oats and barley to Gosnold's Colony in 1602.

BUCKWHEAT.—The first cultivation of buckwheat dates back to 1625 or 1626, on Manhattan Island.

[1] Most of the statements under this head are taken from Eighty Years' Progress of the United States (1861).

[2] Bruce's Economic History of Virginia in the Seventeenth Century, Vol. I, p. 198.

POTATOES.—Plymouth Colony cultivated potatoes as early as 1629.

BEANS.—Beans have the date of 1602 on islands south of Massachusetts, the date of 1644 at Manhattan, and about the same date in Virginia.

FRUITS.—The first apples raised in this country were possibly from trees planted on Governors Island in the harbor of Boston, from which, on October 10, 1639, "ten fair pippins" were brought. Governor Endicott had on his farm in Salem, now Danvers, Mass., in 1640, the first nursery of young fruit trees that was ever planted in this country.

TOBACCO.—The English first saw tobacco cultivated and smoked in clay pipes by the Indians of Virginia in 1585, and the cultivation of tobacco was introduced into the Dutch Colony of New York as early as 1646, when it sold for 40 cents a pound.

FLAX AND HOPS.—Flax was taken to Holland from Manhattan Island as early as 1626. Hemp and flax were raised in Virginia prior to 1648. Hop roots were ordered by the governor of Massachusetts Bay as early as 1628.

SILK.—Silk culture was begun in Louisiana by the Company of the West in 1718. It was introduced into Georgia in 1732. Connecticut began the production of silk in 1760.

SUGAR CANE.—Sugar cane was first introduced into Louisiana in 1751, and the first plantation was established in 1758.

RICE.—The culture of rice was introduced into the colony of Carolina about 1694, the seed being obtained by the governor of the province from a ship from Madagascar.[1]

COTTON.—A pamphlet published in London in 1609 predicts that cotton would grow as well in Virginia as in Italy, and the author of another pamphlet, published in 1620, mentions cotton as a product that may be had in abundance in Virginia; but Bancroft's History of the United States says the first experiment in cotton culture in the Thirteen Colonies was made in Virginia in 1621, when the cotton seeds were planted as an experiment, and their "plentiful coming up" was at that early day a subject of interest in America and England. Cotton wool was listed in that year at 8 pence a pound, which indicates that it may have been grown earlier.[2]

FIRST DOMESTIC ANIMALS.

For many months after the arrival of the Pilgrims at Plymouth they had no beasts of burden; when at last a few cows were brought over they were poorly fed on the coarse wild grasses, and often they

[1] Pitkin's Statistical View of the Commerce of the United States of America (1816), p. 97.

[2] The Cotton Plant; published by the United States Department of Agriculture, pp. 30 and 31.

died from exposure and want of proper food or fell a prey to the wolves or the Indians. Owing to the difficulties and expense of importation, the price was so high as to put them beyond the reach of many even in moderate circumstances. In the colony of Massachusetts Bay a red calf soon came to be cheaper than a black one on account of the greater probability of its being mistaken for a deer and killed by wolves.

CATTLE.—When cows were so high as to sell, in 1636, at from £25 to £30 sterling at Plymouth and oxen at £40 a pair, a quart of new milk could be bought for a penny. The ox of that day was small, ill-shaped, and in every way inferior to the ox of the present time. During the early part of the last century the average gross weight of the neat cattle brought for sale to the Smithfield market was not over 370 pounds.

Dairy cattle were first brought to Virginia in 1611 and to Plymouth in 1624, from the coast of Devonshire. Some of the Virginia cattle were from the black cattle of Spain, and those brought to New York, possibly from the island of Texel on the coast of Holland, were mostly, without doubt, the black and white Dutch cattle. Those on the Delaware were brought from Sweden; those in New Hampshire were the large yellow Danish cattle, and, as the earlier importations were the most extensive that were made for many years, these various stocks were crossed and thus formed the original stock of the country.

The cattle along the northern Atlantic coast fared miserably in winter, having little or no protection from storms and cold and being poorly fed on hay made from overripe swale grass and salt grass cut from the marshes. It was a common opinion in the Virginia Colony that the housing and milking of cows in the winter would kill them.

HORSES.—The first horses taken from Europe to the Western Hemisphere were brought over by Columbus on his second voyage, in 1493. In 1527 forty-two horses were landed in Florida and perished soon after their arrival. The wild horses of the Southwest are probably descendants of the fine Spanish horses abandoned by De Soto on the failure of his expedition. In 1604 a French lawyer brought over horses to Acadia, and these probably laid the foundation of what are now known as Canadian ponies. In 1609 horses were brought to Jamestown, and in 1629 they were introduced into the colony of Massachusetts Bay. Horses were brought to New York in 1625 from Flanders. These importations seem to have been the original stock from which the race of American horses was constituted. But the horses of the United States, as in the case of other farm animals, have been much improved and diversified in special qualities during the last twenty-five years or so by the importation of thoroughbreds from Europe and by well-directed breeding.

SHEEP.—It is probable that the first sheep in this country came to Virginia in 1609 from England. About 1625 some sheep were brought to New York by the Dutch West India Company from Holland. Sheep were brought into the Plymouth Colony and that of Massachusetts Bay very soon after the settlement.

SWINE.—De Soto probably brought the first swine into this country in 1538 from Cuba, and these were landed in Florida. They were probably descended from some brought over by Columbus in 1493. The Portuguese brought swine into Nova Scotia and Newfoundland as early as 1653. The London Company imported swine into Virginia in 1609. They were introduced into the Plymouth Colony in 1624 by Governor Winslow, and into New Netherlands, now New York, in 1625 by the Dutch West India Company.

TRANSITION TO MORE RECENT CONDITIONS.

Although the early white settlers immensely improved and expanded the agriculture of the Indians, it is nevertheless true that in comparison with the agriculture of the present time that of the previous century and of the earlier half of the present century was crude, wasteful, uneconomical, expensive, laborious, and unscientific. The transition from the old to the new was gradual, but, having in mind long periods of time, it is apparent that American agriculture has had two distinct periods with regard to the characterization above specified. The change has been rapid since the civil war, and the last thirty years or so stand out conspicuously as belonging to a period of development and results, having little similarity to the long preceding period beginning with the eighteenth century and approaching an end about the middle of the present one.

In this paper only a brief mention will be made of some of the causes and opportunities of the agricultural expansion of the country.

EXPANSION OF POPULATION.

The principal opportunity for agricultural expansion was the immense cultivable area of virgin soil awaiting primarily to be despoiled of its fertility, which was subsequently to be partly restored and maintained by means of fertilizers.

The necessity for this expansion was a rapid and permanent growth of sturdy population, derived not merely from a natural increase, but largely from an unprecedented immigration from the peasant laboring classes of Europe—people who had been unable to obtain the ownership of land in a country of primogeniture, as well as people who had failed in other countries where land values were beyond their reach, and who came here with "a land hunger," where they found millions of fertile acres awaiting their acquisition at a cheap price.

The population of this country, according to the census of 1790, was 3,929,214; in 1850 it had increased to 23,191,876; in 1860, to 31,443,321; in 1880, to 50,155,783; in 1890, to 62,622,250; and various estimates of the population in 1900 place it at a figure somewhat above 75,000,000. Immigrants, who are included in these figures, numbered 143,439 in the ten years 1821–1830; from about 2,500,000 to 3,000,000 in each of the ten-year periods beginning with 1851 and ending with 1880, and 5,246,613 in the ten years 1881–1890. From 1891 to 1899, inclusive, the number was 3,396,011.

THE NONAGRICULTURAL POPULATION.

Since the birth of the nation there must be taken into account also the great and relative increase in the city population, which must derive its subsistence mainly from the agriculture of this country without contributing to agricultural production. The population living in cities and towns of 8,000 or more was 3.35 per cent of the total in 1790, 12.49 in 1850, 22.57 in 1880, 29.20 in 1890, and perhaps is about 35 per cent at the present time, or more than one-third of the entire population.

These percentages do not include the inhabitants of villages, towns, and the smaller cities not engaged in agriculture, who, if included, would swell the percentage above 35.

There has been a further marked increase in the nonagricultural elements of the population. In 1870 the persons 10 years of age and over who were engaged in manufacturing and mechanical industries were 19.61 per cent of the total number of persons of that age having gainful occupations, and this percentage had increased to 22.39 in 1890. It may easily be 25 per cent at the present time.

The number of persons employed in trade and transportation has increased from 9.83 per cent of the total number of persons employed in all occupations in 1870 to 14.63 per cent in 1890.

The percentage for persons engaged in professional services has increased from 2.97 in 1870 to 4.15 in 1890. For domestic and personal service the percentage has increased from 18.48 in 1870 to 19.18 in 1890.

The census group of occupations embraced within agriculture, fisheries, and mining is represented by 49.11 per cent in 1870, or nearly one-half of the persons having gainful occupations, and fell to 39.65 per cent, or about two-fifths, in 1890, and is likely to be hardly more than one-third at the time of the Twelfth Census (1900).

PUBLIC LAND.

While marked increase in the demand for agricultural products for consumption by persons who are in nonagricultural occupations has thus occurred, the Government at the same time has offered to agricultural producers a vast area of land at hardly more than a nominal price. Previous to July 1, 1897, final homestead entries to the number of 529,051 had been made for 70,396,856 acres belonging to the National Government; the number of entries in the following year was 22,281, covering 3,095,018 acres, and in the year previous to July 1, 1899, the number was 22,218, covering 3,134,149 acres—total to 1899, entries, 573,550; acres, 76,626,023.

During the twenty-two years preceding July 1, 1897, the public and Indian lands disposed of for cash and under the homestead laws, under the timber-culture laws, located with agricultural college and other kinds of scrip, located with military bounty land warrants, and selected by States and railroads embraced 299,961,357 acres; in 1898, 8,453,897 acres; in 1899, 9,182,413 acres—total for twenty-four years, 317,597,667. Some of the States and many railroad companies have been selling land, mostly for farms, amounting in the aggregate to a vast area. The number of sales on credit of tracts of land large enough to be measured by acres, from 1880 to 1889, inclusive, was 60,431 by States and 140,190 by railroads.

CAUSES OF INCREASED PRODUCTION.

While the country has been developing as above indicated, the great nonagricultural populations of European countries have been relatively increasing, and have exhausted in their consumption the farm production of their own countries, especially with respect to the items of wheat, corn, and other cereals, animal and dairy products, and, to the very small extent of cultivation, tobacco and cotton, thus opening up a foreign market, which has in a large degree warranted the expansion of the agriculture of the United States, along with the other causes or opportunities mentioned.

The decided decline in the cost of transportation has also contributed largely to the transformation under consideration.[1]

IMPLEMENTS AND MACHINES.

The most prominent feature in the development of American agriculture is the immense improvement that has taken place in agricultural methods and machines—indeed, the word improvement is not adequate to express the change that has taken place in the methods of agriculture in this country, because the implements and machines are creations rather than improvements, and their mission has been radical and far-reaching. They have reduced the amount of human labor required to produce a given quantity of crops and to cultivate given areas of land, and they have been largely, if not chiefly, instrumental in converting local markets into world markets for the principal cereals, cotton, tobacco, and animal and dairy products.

A technical description of these implements and machines can not be attempted here, and it will be sufficient merely to indicate generally changes in their character and in the results of their work.

[1] The development of transportation facilities in the United States is the subject of another article in this Yearbook.—Ed.

Dependence must be placed upon the reader's knowledge of these machines and upon his mechanical mind to understand how and why they have contributed so much to the realization of the present agricultural era.

VEHICLES.—At the beginning of this century carts were used on the farms and chaises on the roads. Stagecoaches were used on the main roads of travel, and a few wagons were found here and there. Carts were more convenient for use with oxen on the farms. For many years discussion was active as to the comparative economy of oxen and horses for farm use, and wagons came in with the increased use of horses and the improvement of the country roads. Buggies and trotting horses grew up together. Light one-horse wagons first appeared in Connecticut about 1830, but it was not until 1840 or later that they became common enough not to attract notice when seen on the roads.[1]

PLOWS.—In 1637 there were but 37 plows in the colony of Massachusetts Bay. Twelve years after the landing of the Pilgrims the farmers around Boston had no plows, and were compelled to break up the ground and prepare for cultivation with their hands and with rude and clumsy hoes and mattocks. It was the custom in that part of the country, even to a much later period, for anyone owning a plow to do the plowing for the inhabitants over a considerable extent of territory. A town often paid a bounty to anyone who would buy and keep in repair a plow for the purpose of going about in this way.[2]

Mr. C. C. Coffin thus mentions the plow that his father used: "I think it was about 12 feet long. I know that it required eight to ten oxen to draw it, one man to ride upon the beam to keep it in the ground, and a man to follow behind with a heavy iron hoe to dig up the baulks."[3]

A writer in the Rhode Island American in 1820 describes the plow generally in use in the Eastern States at that time, known as the Old Colony plow, as follows: "It had a 10-foot beam and 4-foot land side; your furrows stand up like the ribs of a lean horse in the month of March. A lazy plowman may sit on the beam and count every bout of his day's work. Six of these plows cost me on an average, last year, $5 each to keep the shares and coulters fit for work, and the wear of the other parts could not be less than $1 more—$6 per year for each plow."

The first patent for a plow in this country was taken out by Charles Newbold, of New Jersey, in 1797. His was the first cast-iron plow

[1] A Century of Connecticut Agriculture, by Prof. William H. Brewer, Twenty-eighth Annual Report of the Secretary of the Connecticut Board of Agriculture, 1894, p. 49.

[2] Eighty Years' Progress of the United States, p. 27.

[3] Arguments before the Committee on Patents of the Senate and House of Representatives, 1878, p. 272.

ever made, but the farmers in those times entertained great prejudices against it. There was a general idea throughout the country that a cast-iron plow would "poison" the land. Mr. Coffin remembers the first cast-iron plow used in his neighborhood in New Hampshire in 1837 and the assemblage of farmers who objected to it for the reason mentioned. He says that it required from 1797 to 1842 for the inventive genius of this country, together with the observations of farmers and mechanics, to arrive at any just conclusion as to what would be the best form for the plow.

Without mentioning intermediate plows, it will be sufficient to pass on to the Oliver chilled plow, which first appeared in 1870. This was a light, durable plow with a mold board of proper shape to economize draft and suitably turn the furrow, and this plow in a marked degree promoted the economy of plowing. It was stated by Mr. Coffin in 1878 that this invention, if used throughout the United States in the preceding year, would have effected a saving of $45,000,000 to the farmers of the country in the expense of plowing.

And then invention followed invention and improvement followed improvement, until we have sulky plows, gang plows, plows combined with harrow cultivators and with seed drills, side-hill plows, vineyard plows, beet plows, subsoil plows, double land-side plows, and lastly, what has been the aim, and seems to be the end, of plow invention, we have the steam gang plow combined with a seeder and a harrow, which has reduced the time required for human labor (in plowing, sowing, and harrowing) to produce a bushel of wheat, on an average, from 32.8 minutes in 1830 to 2.2 minutes at the present time, and which has reduced the time of animal labor per bushel from 57 to 1½ minutes; at the same time it has reduced the cost of human and animal labor in plowing, seeding, and harrowing per bushel of wheat, from 4 cents to 1 cent.

CORN PLANTERS.—Hundreds of patents have been issued for corn planters. The earlier ones were adjustments to the hoe, which permitted the release of grains of corn when the hoe was struck into the ground; then came the hand planter, and the next step was the horse drill. Next came the idea of marking rows in both directions with a drag. A long beam with pins in it was dragged both ways across the field by horses, and then the farmer would go along with the hand planter and plant the corn at the intersection of the rows. Still, again, followed an improvement, and this was the corn planter which planted two rows at one time with the rows running in both directions. A man sat on the machine, and, at every point where the drag had crossed at right angles, he moved a lever that dropped the corn, which was covered by wheels that turned and pressed down the soil upon the seed. The check rower followed; it was a simple implement, consisting of a wire chain or knotted rope stretching across the field and anchored at both ends. This passed through the machine as it was driven across the field and dropped some grains of corn every time the knot passed through a slot in the machine. It was only necessary to drive backward and forward all day long until the acres were planted, and then the corn could be cultivated in both directions. Subsequently, numerous check-row planters for corn have been invented with and without fertilizer adjustments, so that several rows of corn may be planted at the same time in places at regular distances apart, permitting cultivation in both directions.

CULTIVATORS.—Cultivators have been the subject of several thousands of patents. The original cultivation of corn and other crops planted in rows was by means of the hoe, but in the course of time a plow was used to loosen the earth and to suppress weeds and grass, being drawn twice between the rows and turning the soil against one or the other. Next a tooth harrow was employed, and this was drawn one way between the rows, and afterwards a cultivator with small double plowshares was used. Then followed the double-shovel cultivator, cutting deep or shallow, as desired, and turning the earth toward two opposite rows at the same time. The implement is now variously made, but it has reduced the economy of cultivation apparently to a minimum; the farmer may now ride while the cultivator is doing its work. He cultivates the rows of his crop in both directions, and the use of the hoe has been nearly, if not entirely, discontinued throughout large agricultural areas.

HARROWS.—Much attention also has been devoted to the invention of implements for harrowing and pulverizing the soil. The farmer no longer drives a brush harrow over his field as of yore, nor does he need to use a tooth harrow, but he has at his command disk harrows, screw pulverizers, smoothing harrows, spring-tooth harrows, and harrows combined with plows and seeders.

CORN HUSKER.—The mechanical corn husker is a machine of recent invention. Previously the husking of corn was done only by hand, and a peg strapped to the hand was often used for opening the husks; but there is now a machine that husks the corn and at the same time cuts the husks, stalks, and blades into feed, the motive power being steam.

CORN HARVESTER.—Again, we have the recent corn-harvesting machine drawn by horses that cuts the cornstalks and binds them into bundles at the same time.

CORNSHELLERS.—The steam cornsheller caused a remarkable change in the time and expense of the shelling of corn. In the olden time corn was shelled by hand, a frying-pan handle or shovel being used, the ears of corn being scraped against it, or perhaps the cob of one ear was used to shell the corn from another. Then came the first machine for shelling corn, a cylinder turned by a crank, by which a man might shell about 40 bushels in a day. Thousands of patents have been issued for cornshellers, and the culmination of them is the steam-power or horse-power cornsheller, which will shell a bushel a minute, carry off the cobs to a pile or into a wagon, and deliver the corn into sacks or wagons.

SEEDERS.—From the time when wheat was first sown, up to a comparatively recent period, the only method of sowing it was to throw it into the air by the hand. In this way it is impossible to sow evenly, especially if the wind blows with considerable force; and if clover seed is to be sown, the ground must be gone over a second time, while a third time is required if fertilizer is to be distributed. Then, when the harrow comes some of the grains are buried too deeply and some are not covered with earth enough. But not so many years ago inventors set to work to construct mechanical seeders, and the result is an almost complete abandonment of broadcast sowing by hand and the substitution of such seeders. They sow all kinds of grain and seeds at once, with fertilizer if required, and they harrow at the same time. They make the crop more certain. It is the general opinion that the wheat crop is increased one-eighth or more by the use of the mechanical seeders, especially in the case of winter wheat.

MOWERS AND REAPERS.—In 1794 a Scotchman invented what was described as a most marvelous and wonderful machine for cutting grain, doing as much in one day as seven men could do with the sickle. This marvelous machine was only the cradle. The reaper followed, and the first patent for one issued in this country was given to Hussey in 1833. McCormick took out his first patent in 1834, although he had constructed and tested a machine in Virginia in 1831 with some success; but the world heard little of reaping machines until 1845, when 150 of them were built at Cincinnati; by 1846 fully 300 had been built. There was a general trial of mowers and reapers at Geneva, N. Y., in 1852. Nine machines contested, for other inventors had taken out patents. Nineteen years had passed since the first patent had been issued. Out of the nine machines exhibited, not one could start in the grain without backing to get up speed. There was a heavy side draft, the machines were clumsy, and they could not turn easily.

By 1855 about 10,000 mowers and reapers had been built by different makers, nearly all being one-wheeled machines. There was an exhibition of reapers at the French exposition in 1855, in which there was one English, one French, and one American. The French machine did its allotted work in 72 minutes, the English in 66, and the American in 22.

Two years later, in 1857, there was a trial at Syracuse, N. Y., at which nineteen machines contested. Of these, all except three started in the grain without backing to get up speed. There was a trial at Auburn, N. Y., in 1866, at which forty-four different machines were entered, and of these, forty-two did their work in a satisfactory manner.

The mower and reaper combined cut the grain and left it on the ground bunched up in proper size for a sheaf, subsequently to be bound by hand. The harvester was supposed to be an improvement upon this, because it had a place for one or two men to ride to bind the grain as fast as it was cut; but the self-binder went beyond that and by means of a mechanical attachment did the binding without the aid of human labor. It was not until 1870 that the self-binder was a mechanical success; but that was not the end of invention for constructing machines to harvest wheat.

It remained for the ingenuity of man to construct a combined reaper and thrasher, with which it is necessary only to drive across the wheat field in order to obtain the grain ready for transportation to the elevator or elsewhere.

COTTON GIN.—Without the cotton gin it would be practically impossible to raise and market the cotton crop of this country, which now commonly amounts to 10,000,000 bales and more annually. Before Whitney's invention it is said that the labor of one person was required for about ten hours to pick the seeds from 1½ pounds of cotton lint. At the present time one machine will gin from 1,500 to 7,500 pounds of lint in the same time, the quantity varying according to the size and power of the gin.

INFLUENCE OF PATENT LAWS ON DEVELOPMENT OF AGRICULTURAL MACHINES.

The development and creation of agricultural implements and machines by the inventive genius of this country is one of the most remarkable features of progress of the century. Its history is one of evolution and revolution—a revolution of incalculable consequences to human labor and the production and distribution of wealth, with an immense bearing upon the trend and character of industry, social life, and civilization.

This development has been encouraged by the patent laws of the country, and perhaps nothing could be more tersely expressive of the influence of these laws in promoting mechanical agriculture than a mention of the number of patents that have been granted. Under date of November 17, 1899, the Patent Office reports that patents for agricultural machines had been granted to the number indicated in each of the following classes: Vegetable cutters and crushers, 701; fertilizers, 822; bee culture, 1,038; trees, plants, and flowers, 1,102; care of live stock, 3,749; dairy, 4,632; thrashers, 5,319; harrows and diggers, 5,801; fences, 8,404; seeders and planters, 9,156; harvesters, 12,519; plows, 12,652.

It is no longer necessary for the farmer to cut his wheat with sickle or cradle, nor to rake it and bind it by hand; to cut his cornstalks with a knife and shock the stalks by hand; to thrash his grain with a flail, nor to drive horses over it to tread it out, nor to scrape the ears of corn against a shovel or the handle of a frying pan. It is no longer necessary for him to dig potatoes, nor to cut his grass with a scythe and to spread it with a pitchfork that it may dry, nor to pitch the hay from the wagon to the haymow in the barn, nor to pick the lint from cotton seed by hand, and so on with numerous operations throughout the whole range of agricultural work.

Mechanical contrivances have largely supplanted human labor in many respects, or have improved the application of labor and increased the product of agriculture, reduced the cost of production, augmented the farmer's gross income, and made his life an easier one than it was before the machine period.

This country has come to be without a peer in the manufacture of agricultural implements and machines, both in quality and number. The manufacturing establishments for producing them in 1890 numbered 910, with a capital of $145,313,997 and 42,544 employees, receiving wages to the amount of $21,811,761, turning out a product valued at $81,271,651. One of these establishments (the largest in the world), making various kinds of mowers and reapers, corn harvesters, corn huskers and shredders, and hayrakes, turned out 187,760 machines in 1898, or, on an average, one in less than a minute for every working day.

AGENCIES FOR AGRICULTURAL EXPERIMENT AND INFORMATION.

Along with the application of invention, have grown up numerous agencies for educating and training the farmer in agriculture, for disseminating information with regard to improvements, and for stimulating among farmers the associative spirit and increasing the benefits to be derived from cooperation.

The first of these agencies, chronologically, consisted of voluntary organizations for the promotion of agricultural interests. These, under various titles, existed in the colonies even before the beginning of this century. We have records of five established during the decade of 1785–1794, in the following States and in the order named: Pennsylvania, South Carolina, New York, Massachusetts, and Connecticut. This method of aid to agriculture has constantly increased during the nineteenth century, and agricultural societies, the name generally applied to them, have multiplied so that at the present day there are probably few counties in the United States where some form of agricultural society does not exist, while all the leading agricultural industries are represented by State, and, in many cases, by national organization.

Many of these voluntary associations receive State aid, and especially is this true of those organized mainly for the purpose of holding annual fairs. About 1,500 such associations are now in existence, extensively distributed throughout the country, but more especially throughout the North Central and North Atlantic States. Of farmers' clubs, it is sufficient to say their name is legion. Another of these agencies consists of the commissioners of agriculture or boards of agriculture of the different States, and almost every State has some official organization in the interests of agriculture. To these must be added the agricultural colleges and the experiment stations, in which the Federal and State governments cooperate.[1]

Finally, the most important of the agencies referred to is the Department of Agriculture itself, which began as an insignificant division in the Patent Office, Department of the Interior, in 1839, became a Department under a Commissioner in 1862, and in February, 1889, was erected into an Executive Department under a Secretary, who is a member of the Cabinet.

STATISTICS.

AGRICULTURAL CENSUSES.

Important and extensive collections of statistical information with regard to farms and their products have been made by national and State censuses.

The first statistics of agriculture collected by a United States census were obtained in 1840, within limits much narrower than those adopted in the censuses of 1890 and 1900.

At the present time it is the policy of the Census Office to procure an inventory of farm property and products, with detailed statements for acreage, values, quantities, and numbers of live stock, as far as applicable. It is expected that the national census of this year will procure many facts with regard to the farms of this country, which are now supposed to number about 5,000,000. No other country takes such a thorough, extensive, and detailed census of agriculture as does the United States.

The use of the censuses of agriculture might be the subject of extended discussion, but comparatively little can be said here. Not a day passes that the Department of Agriculture does not need to use census statistics of agriculture in many ways and for many purposes, not only in its own routine work of crop estimates and in the preparation and conduct of statistical investigations, but also in response to numerous letters received from residents of the United States and foreign countries.

Some of the States are required by their constitutions, or by legislative enactments, to take censuses, but not all of them comply with the requirement. The most elaborate State census of agriculture is taken by Massachusetts. Among the other States required to take

[1] No attempt is made here to explain even briefly the work of the agricultural colleges and experiment stations as a factor in the development of agriculture, both agricultural education, during this century, and the work of the agricultural experiment stations being treated at length in other papers in this Yearbook.—Ed.

censuses are Indiana, Iowa, Kansas, Michigan, Oregon, Oklahoma, and Wisconsin.

Useful agricultural statistics are collected and published also by the boards of agriculture of the several States, notably by the States of Texas and Kansas.

BOARDS OF TRADE AND COTTON EXCHANGES.

At least twenty-five boards of trade publish statistics of the movement, distribution, prices, etc., of agricultural products, and the following is substantially a complete list of the cities in which these boards of trade are situated, the variants of the name being sometimes merchants' exchange, chamber of commerce, produce exchange, or commercial exchange: Baltimore, Md.; Boston, Mass.; Buffalo, N. Y.; Chicago, Ill.; Cincinnati, Ohio; Denver, Colo.; Detroit, Mich.; Duluth, Minn.; Indianapolis, Ind.; Louisville, Ky.; Memphis, Tenn.; Milwaukee, Wis.; New York, N. Y.; Omaha, Nebr.; Peoria, Ill.; Philadelphia, Pa. (commercial exchange and also produce exchange); Portland, Oreg.; Richmond, Va.; St. Louis, Mo.; San Francisco, Cal. (chamber of commerce and also produce exchange); Seattle, Wash.; Toledo, Ohio, and Washington, D. C.

Besides the foregoing boards of trade, there are many in the United States whose object is to stimulate concerted action by manufacturers, merchants, financiers, and persons especially concerned in carrying on the distributive processes. About 800 of these boards of trade have a national association, which speaks powerfully for interests representing many hundreds of millions of dollars of capital, and which substantially represents the class of persons known as middlemen, who distribute the products of the farm. But this national association does not include all of the boards of trade, chambers of commerce, and produce exchanges. These in the aggregate number between 1,300 and 1,400, the largest number among the States being found in New York; second to which stands Pennsylvania; third, Ohio; and, fourth, Massachusetts.

There is a class of these boards of trade especially concerned with cotton, generally known as cotton exchanges, which are associations of middlemen with the object of obtaining information in regard to the condition of the market as influenced by demand, supply, production, available cotton, and, in some cases, of dealing in futures. The cities and towns where these exchanges are situated are as follows: Eufaula, Birmingham, Mobile, Montgomery, and Selma, Ala.; Little Rock and Texarkana, Ark.; Atlanta, Columbus, Rome, Savannah, and Augusta, Ga.; Monroe, New Orleans, and Shreveport, La.; Greenville, Greenwood, Meridian, Natchez, Vicksburg, and Yazoo City, Miss.; St. Louis, Mo.; New York, N. Y.; Newbern, Wilmington, and Raleigh, N. C.; Charleston and Columbia, S. C.; Memphis and Nashville, Tenn.; Galveston, Dallas, Fort Worth, Sherman, Waco, and Houston, Tex.; Norfolk and Portsmouth, and Richmond, Va.

STATISTICS OF DEVELOPMENT.

The progress of American agriculture up to the present time has by no means been thoroughly discussed in this paper, nor is it possible to do so within the limits of a Yearbook article; hence only a few more topics can be mentioned. First, statistics expressing development will be given.

FARMS AND ACREAGE.—The number of farms increased from 1,449,073 in 1850 to 4,564,641 in 1890. During the same time the total farm acreage increased from 293,560,614 to 623,218,619 acres, of which the increase in improved acreage was greater, both absolutely and relatively, than the increase in the unimproved acreage.

INCREASING IMPORTANCE OF MEDIUM-SIZED FARMS.—The average size of farms declined from 203 acres in 1850 to 137 acres in 1890, and it has been established by a thorough statistical analysis that in the more recent years the increase in number of farms has more largely accrued to farms of medium size than to farms of the smaller and larger sizes. Why this should be so is only a matter of conjecture. It may be that the persons who acquire the proprietorship of farms, either as owners or as tenants, have become more able to acquire the possession of medium-sized farms, and so reject or consolidate the smaller farms; it may be also that the larger farms have not been found to be as profitable as medium-sized farms.

The use of machines is an important element in this country's agriculture, and possibly the medium-sized farm as it exists to-day is susceptible of being more economically cultivated and managed than either smaller or larger farms, and among the economic reasons for this the farm machine must be reckoned as highly important. But whatever the explanation may be, the fact remains that the middle-class farmer, according to the tendency disclosed by the census of 1890, is coming more and more to the front among agriculturists.

FARM REAL ESTATE AND MACHINES.—The value of the real estate of farms increased from $3,271,575,426 in 1850 to $13,279,252,649 in 1890. During this period the value of farm implements and machines increased from $151,587,638 to $494,247,467; but these numbers do not adequately represent the increase in the importance of implements and machines, partly because these figures take no account of the vast increase in their efficiency, which has been infinitely greater than the figures express, and in a very large degree because of the much cheaper prices prevailing in 1890.

FARM PRODUCTS.—The censuses have very poorly ascertained the value of farm products, the statements undoubtedly being considerably under the facts. The published statement of the census of 1890 gives the value of farm products as $2,460,107,454, but an estimate made on the production ascertained in the census of 1890 by Mr. J. R. Dodge, former Statistician of the Department of Agriculture, places the value of farm products in the agricultural year covered by that census at about $3,500,000,000.

FARM ANIMALS have increased as follows, as shown by national censuses: Horses, from 4,336,719 in 1850 to 14,969,467 in 1890; mules and asses, from 559,331 in 1850 to 2,295,532 in 1890; milch cows, from 6,385,094 in 1850 to 16,511,950 in 1890; oxen and other cattle, from 11,393,813 in 1840 to 34,851,622 in 1890; swine, from 26,301,293 in 1840 to 57,409,583 in 1890; sheep, not including spring lambs, from 19,311,374 in 1840 to 35,935,364 in 1890. The wool clip of the census year of 1890 amounted to 165,449,239 pounds. The value of live stock increased during the period 1850–1890 from $544,180,516 to $2,208,767,573.

FARM DAIRY PRODUCTS are thus stated in the census of 1890: Entire number of gallons of milk produced on farms, 5,210,125,567; pounds of butter, 1,024,223,468; pounds of cheese, 18,726,818. It must be remembered that the production of butter and cheese on farms has been largely transferred to creameries, whose products are not included in the foregoing figures, but are included in part in the census statistics of manufactures—only in part, however, because it is known that a very large portion of the creameries and their products were omitted from the census statistics of 1890.

POULTRY.—In 1890 it was reported that the chickens on farms numbered 258,871,125; other fowls, 26,738,315; and that the eggs produced and sold during the census year were 819,722,916 dozen. The poultry statistics, however, probably fall far short of the facts.

CROP PRODUCTION.—Coming now to the production of crops, the following extracts are made from the censuses of 1840 and 1890, to which the figures of the Department of Agriculture for 1899 are added:

Cereals.—Production of indian corn, 377,531,875 bushels in 1840; 2,122,327,547 bushels in 1890; 2,078,143,933 bushels in 1899; and the corn acreage increased from 62,368,504 acres in 1880 to 82,108,587 acres in 1899.

The wheat product was 84,823,272 bushels in 1840; 468,373,968 bushels in 1890; 547,303,846 bushels in 1899; and from 1880 to 1899 the wheat acreage increased from 35,430,333 acres to 44,592,516 acres.

The United States produces more wheat than any other country in the world. A comparison may be made for 1898: Crop of the United States, 675,149,000 bushels; France, 371,881,000 bushels; Austria-Hungary, 170,938,000 bushels; Italy, 133,372,000 bushels; Germany, 115,000,000 bushels; United Kingdom, 77,170,000 bushels; Russia in Europe, 404,836,000 bushels; Russia in Asia, 94,000,000 bushels; total Asiatic production, 421,321,000 bushels; total African production, 44,439,000 bushels; total South American production, 72,000,000 bushels.

The oat product was, in bushels, in 1840, 123,071,341; in 1890, 809,250,666; in 1899, 796,177,713. The oat acreage was 16,144,593 in 1880, and increased to 26,341,380 acres in 1899.

The rye product was 18,645,567 bushels in 1840, 28,421,398 bushels in 1890, and 23,961,741 bushels in 1899, with a decrease of acreage from 1,842,233 acres in 1880 to 1,659,308 acres in 1899.

Cotton.—The cotton crop of 1850 amounted to 2,469,093 bales, and the crop increased decennially up to the census of 1890, and almost without a break annually since that year until the enormous crop of 1898–99, which amounted to 11,189,205 bales of considerably heavier weight than the bales of 1850. The cotton acreage increased from 14,480,019 acres in 1880 to the largest acreage yet attained, in 1898–99, which was 24,967,295. The cotton crop of the United States substantially dominates the world market for cotton, its proportion of the world's crop being from 80 to 85 per cent, and practically having little competition within the lines of its own grades and qualities. The State of Texas alone produces more cotton than any foreign cotton-producing country.

Hay.—The hay production amounted to 10,248,109 tons in 1840; to 66,831,480 tons in 1890, and to 56,655,756 tons in 1899; and the acreage increased from 30,631,054 acres in 1880 to 41,328,462 acres in 1899.

Tobacco.—From 1840 to 1890 the production of tobacco increased from 219,163,319 pounds to 488,256,646 pounds, and the acreage in the latter year was 695,301 acres.

Potatoes.—White potatoes are a crop of extraordinary increase, the bushels in 1850 being 65,797,896; in 1890, 217,546,362, and in 1899, 228,783,232. From 1850 to 1890 the production of sweet potatoes increased from 38,268,148 to 43,950,261 bushels.

AGRICULTURAL EXPORTS.

The development of the agriculture of the United States has much more than kept pace with the enormous immigration, increase of population, increase of domestic consumption for food and manufactured products, and for cattle and other domestic animals. It has furnished besides an enormous surplus for export. Only the exports of the principal products can be given briefly:

WHEAT.—The wheat export was 4,272 bushels in 1823; 4,155,153 bushels in 1860, and 139,432,815 bushels in 1899. During the same time wheat flour was exported to the amount of 756,702 barrels in 1823, 2,611,596 barrels in 1860, and 18,502,690 barrels in 1899.

COTTON.—The exports of raw cotton amounted to 173,723,270 pounds in 1823, to 1,767,686,338 pounds in 1860, and to 3,773,410,293 pounds in 1899. The more recent product, cotton-seed oil, had an export of 50,627,219 gallons in 1899, and the export trade in this product has chiefly grown up since 1889.

HAY AND BARLEY.—The hay export is relatively small, amounting to only 64,916 tons in 1899. The barley export also is comparatively small, amounting to 2,267,400 bushels in 1899, although it reached its maximum amount of 20,030,301 bushels in 1897.

CORN.—The corn export was 749,034 bushels in 1823; it was 3,314,155 bushels in 1860, and 174,089,094 bushels in 1899. In addition to the unmanufactured corn exports are the exports of corn meal, and these amounted to 791,488 barrels in 1899; but a large portion of the corn product is consumed by domestic animals, the exports of which are mentioned below.

OATS AND RYE.—In 1899 the oat export amounted to 30,309,680 bushels, and the oat-meal export was 58,042,505 pounds. In the same year the rye export was 10,140,876 bushels, and the rye-flour export 4,826 barrels.

ANIMALS AND ANIMAL PRODUCTS.—The following are the exports of farm animals in 1899, the figures representing numbers of animals: Cattle, 389,490; hogs, 33,031; horses, 45,778; mules, 6,755; sheep, 143,286. These numbers have grown during the last twenty-five years from almost nothing.

The exports of beef products amounted to 19,053,800 pounds in 1866, not including preserved meats, and the entire quantity of beef products exported in 1899 was 368,666,638 pounds; in the latter year the beef-tallow exports amounted to 107,361,009 pounds. In 1866 the pork products exported amounted to 97,756,169 pounds, and the number had grown to 1,700,380,357 pounds in 1899. In 1899 the mutton exports amounted to 379,110 pounds.

A large item of export has grown up within a few years under the name of oleo oil, and its export in 1899 aggregated 142,390,492 pounds.

The butter and cheese exports have in late years shown a decline, and in 1899 they amounted, respectively, to 20,247,997 and 38,198,753 pounds.

TOBACCO.—For many years tobacco has been a large item of export, and its quantity has substantially remained constant for twenty-five years or so. The pounds of leaf tobacco exported in 1899 were 272,421,295 and the value of the manufactured tobacco exported in that year was $5,179,012.

WOOL.—The wool export has rarely reached 1,000,000 pounds, although in 1896 it almost equaled 7,000,000 pounds.

The statistics immediately preceding, as well as the others in this paper, express forcibly and comprehensively, although tersely, the agricultural development through which this country has passed up to the present time—a development which has been unparalleled in the history of the world in its rapidity and magnitude.

FERTILIZERS.

The decade 1840–1850 marks an epoch in the history of agriculture. The world was then making rapid strides in applied science.

Railroads were rapidly extending, ocean steam navigation became established, the electric telegraph came into use, and, what was of great importance in connection with agriculture, the chemical theory of manures came to be understood. "Artificial fertilizers," made according to formulas founded on the chemical composition of the ashes of plants, began to be manufactured, and came rapidly into use. The use of nitrate of soda and superphosphate of lime was becoming common. The rapidity of this growth is perhaps best seen in the rise of the use of guano. Samples had come to Europe early in the century; next a few casks came; in 1840, Liebig, the eminent chemist, brought it into notice, and the South American merchants sold a small cargo that year. The next year some 2,000 tons were imported into Great Britain.

The use of commercial fertilizers has progressed from year to year, until, in 1896, 1,894,917 tons were used in the United States, valued at $37,688,869.

The economic advantages of the use of fertilizers are distinctly shown in an investigation conducted by the Division of Statistics of the Department of Agriculture in 1896. This was a unique investigation of comprehensive character, and was applied to the production of cotton.[1]

Along with the increased consumption of commercial fertilizers, there has been a vastly increasing realization by farmers of the value and utility of barnyard and compost manures, especially in the parts of the country where cattle are kept in stables throughout a large portion of the year. While the average production per acre of various crops has not materially increased for many years past, yet farmers know that they not only must not, but can not, rob the soil of its fertility without restoring the elements that go to make plant growth. In some parts of the country, where the fertility of the soil is materially impaired, it is still the custom to let cultivated land lie fallow for sufficient length of time to increase its fertility, but there is also a large extent of country where this is not done, and where, on the contrary, domestic and commercial fertilizers are liberally used.

Speaking in general for the whole country, the net result of the use of fertilizers, so far, has been mainly to preserve the normal fertility and production of the soil, although farmers' experiences have numerously and extensively established the economic desirability of more intensive agriculture.

EVOLUTION OF VARIETIES OF FOODS FROM PRODUCTS.

There is one prominent feature in the agricultural development of the United States that has received little public attention (a feature which alone is worthy of an extended article), and this is the

[1] See Bulletin No. 16, miscellaneous series, Division of Statistics, U. S. Department of Agriculture, The Cost of Cotton Production.

extraordinary multiplication of the varieties of foods into which farm products have been converted by the slaughterhouse, by the packing house, by the cannery, and by the manufacture of health foods. The effect of all this upon the consumption of numerous farm products has been very considerable, and has, to some extent, revolutionized the diet of the people of this country, and presumably of other parts of the civilized world, especially of people living in cities and towns.

EARLY PRACTICES REGARDING FOOD SUPPLY.

One does not need to go back more than a generation to find the meat supply derived from local farmers and butchers. Indeed, among the great mass of the people living outside of the cities and large towns the fresh-meat supply was a matter of neighborhood borrowing; a farmer slaughtered an old cow, perhaps, and distributed some of the quarters or other portions of the carcass among his neighbors, with the expectation that they would return an equivalent when it came their turn to butcher.

Until comparatively recent years the products of the farm were distributed throughout the year for food consumption in a crude and very restricted sense. Apples and green corn were dried in the sun; indian corn was preserved dry in the crib; potatoes, cabbages, and turnips were kept fresh in the cellar; some beef was dried; pork and beef were pickled in brine; squashes and pumpkins were kept for some time after the harvest without rotting, and so on with a few other products of the farm and garden.

CANNING, PRESERVING, AND REFRIGERATING IN RECENT YEARS.

An immense change in the relation of foods to seasons has taken place within recent years. Fresh beef and mutton and pork and poultry preserved by refrigeration can now be had in all parts of the country from the farms and ranches of the Mississippi Valley, to say nothing of the improved local meat supply. Many of the principal garden products now know no season, owing to the canner and the preserver. The peach and the pear, the apricot and the plum, peas and beans, lentils and green corn and tomatoes, and many kinds of berries—and so on through almost the entire list of the fruit and vegetable products of the farm and garden—are now to be had at all times of the year, not always, perhaps, with the flavor they possessed when gathered from their vines and stalks and trees, but yet with much of their original freshness and flavor.

By means of canning and preserving the farmers' market has been enlarged both in time and space until the market for farm and garden products now extends throughout the entire year, not only to remote parts of this country, but to a large portion of the world.

If a list of the different kinds and descriptions of food were to be presented, it would, because of its magnitude, overtax the patience of the reader. An attempt was made several years ago to prepare such a list for a publisher, and the undertaking had to be abandoned on account of its unexpectedly large proportions and the time, labor, and expense required. In this paper it is proposed merely to give three illustrations of the heterogeneity that has characterized the development of farm products as foods and for other purposes.

BUSINESS OF A PROMINENT PACKING COMPANY.

One of the large Western packing companies with enormous capital and business has been selected to illustrate how the extension of the farmers' market has been promoted and elaborated in recent years. This packing company owns the cars that are used to distribute its products and to collect some of them. It has 500 tank cars for transporting blood and tankage for fertilizers and various animal oils; it has 4,000 cars for transporting dressed beef and 6,500 cars for transporting fruit. From the price lists of this company, sent to its agencies throughout the United States, the following facts are extracted:

The beef carcass is cut into many different parts in various ways, all intended to meet the demands of retailers and consumers, and the different parts so cut, including all of the parts of the animal customarily eaten, number 53. With regard to meat cuttings, the numbers are, pork 29, mutton 12, veal 5; number of boiled hams 6; varieties of sausages 43 and of delicatessen sausage 14—total varieties of sausage 57. The dried salt meats are prepared with 16 different cuttings; the bacon meats with 16.

There are hams of many descriptions, and dried beef, mess pork, mess beef, pickled beef tongue, pork spareribs, mince-meat in packages of numerous sizes, lard, compound lard and lard oil, neat's-foot oil, and tallow oil.

The canned meats include numerous varieties, among which may be mentioned corned beef, pigs' feet, gelatin, boar's head, Oxford sausage, tongue, roast beef, boiled beef, chipped beef, deviled ham, potted ham and tongue, minced ham, chicken, turkey, chile con carne, pork and beans, ox marrow, chicken tamale, and sauerkraut and Vienna sausage, etc.

There are to be mentioned also some of the canned soups, as ox tail, mock turtle, tomato, consommé, chicken, beef, mutton, vegetable, purée of green peas, and so on.

The extracts of beef are liquid and in tablets of various descriptions. The pickled tongues, pork hocks, and pigs' feet are of nine descriptions, and there is poultry of all sorts and fresh eggs and canned eggs, ducks, quails, venison, prairie chickens, pigeons, squabs, and even frogs' legs.

COTTON SEED.

Cotton seed is a very marked instance of a former by-product of the farm which has become of enormous value and of varied uses.

The meats are made into oil cake and oil meal for feeding stuff and for fertilizers; into crude oil, cotton-seed stearin, salad oil, cottolene, miners' oil, and soap, and the oil is exported to Europe and brought back again as olive oil. The hulls may be used for making paper; they are made into bran for cattle food; they are used for fuel, and are an important contribution to the list of fertilizers.

Here is an enormous source of wealth which science has given to the farmers within comparatively recent years. The estimated value of the cotton seed of a 10,000,000-bale crop of cotton (to the planters) is about $30,000,000, and this value is now almost entirely appropriated by them.

DIVERSIFICATION OF DAIRY PRODUCTS.

Only one more instance of the elaboration of the products of the farm need be mentioned to illustrate how varied the farmers' market has become and how minutely his products have been made to create and answer the wants of mankind. The following are the varieties of the dairy products of the United States, as furnished by Maj. H. E. Alvord, chief of the dairy division, Bureau of Animal Industry:

Butter.

Dairy and Creamery: In tubs, boxes, family packages, rolls, and prints.
Imitation Creamery: Ladled, Renovated, or "Process," all melted and rechurned.
Fresh or "Sweet;" that is, unsalted.

Cheese.

I. Hard: (*a*) Domestic varieties:
- Factory Standard, or Cheddar.
- English Dairy.
- Young America.
- Little Favorites. } Differing in size and form rather than in character.
- Picnics.
- Ponies.
- Skim cheese.
- Pineapple.
- Sage.

(*b*) Foreign forms, imitated:
- Swiss, or Gruyere.
- Edam.
- Gouda.
- Limburger.
- Munster.
- Brick.

II. Soft: Pot cheese, or Smearcase.
- Neufchatel.
- Cream.
- Isigny.
- Brie.
- Camembert.
- Potted and prepared cheese, "Club-house," etc.

Milk, etc.

Condensed milk, sweetened.
Condensed milk, plain, or unsweetened.
"Evaporated cream."
Cream, sterilized and canned.
Milk and cream, Pasteurized, "Certified," "Modified," etc.
Koumys, Matzoon, Wheyn, etc.

SOME ECONOMIC RESULTS OF MACHINES.

Much remains to be said with regard to the evolution of agriculture in the United States, but only a brief reference can be made to some of the more important results of the investigation of hand and machine labor and processes as applied to agriculture, with a contrast between farming as it was practiced fifty to seventy years ago and farming as it is now carried on with the advantage of the labor-saving and perfecting implements and machines of the present time as well as with the improvements contributed by the chemist, the "book farmer," and the more enlightened experience of the last half century.[1]

CORN CULTIVATION AND HARVESTING.

Between 1855 and 1894 the following changes took place in the cultivation of corn. The time of human labor required to produce one bushel of corn on an average declined from 4 hours and 34 minutes to 41 minutes, and the cost of the human labor to produce this bushel declined from 35¾ cents to 10½ cents.

In the earlier years the plow and harrow of that period were used; the check rows were marked with the shovel plow; the seed was dropped by hand from a bucket or pouch carried by the farmer and covered with a hoe; the cultivating was done with a shovel plow; knives were used for cutting the stalks from the ground by hand; husking pegs were worn on the hand in husking; the stalks, husks, and blades were cut into fodder with an old-time machine turned by hand, and the corn was shelled by hand, either on a frying-pan handle or on a shovel or by rubbing the cob against the unshelled ears.

A radical change had taken place in 1894. The earth was loosened with a gang plow, and a disk harrow very thoroughly pulverized it. A corn planter drawn by a horse planted the corn, and the top soil was pulverized afterwards with a four-section harrow.

When it came to harvesting the corn, a self-binder drawn by horses cut the stalks and bound them, and the shocks of stalks were then hauled to a machine, which removed the husks from the ears, and in the same process cut the husks and the stalks and the blades into fodder, the power of the machine being supplied by a steam engine.

[1] Report of the United States Department of Labor on Hand and Machine Labor, 1898.

Then came the shelling of the corn, which is one of the marvels of the changes that have been wrought by machines. In this case, the machine operated by steam shelled 1 bushel of corn per minute, while in the old way the labor of one man was required for 100 minutes to do the same work.

WHEAT CULTIVATION AND HARVESTING.

The use of steam as a substitute for horse power in plowing, in harvesting, and in thrashing wheat has not materially contributed to economy, except from a saving due to the elimination of animal power, so the more common power supplied by horses is here selected for the comparison. The years in contrast are 1830 and 1896.

It is one of the marvels of the age that the amount of human labor now required to produce a bushel of wheat from beginning to end is on an average only 10 minutes, whereas, in 1830, the time was 3 hours and 3 minutes. During the interval between these years the cost of the human labor required to produce this bushel of wheat declined from 17¾ cents to 3⅓ cents.

In the contrast thus presented the heavy, clumsy plow of the day was used in 1830; the seed was sown by hand, and was harrowed into the ground by the drawing of bushes over it; the grain was cut with sickles, hauled to a barn, and at some time before the following spring was thrashed with flails; the winnowing was done with a sheet attached to rods, on which the grain was placed with a shovel and then tossed up and down by two men until the wind had blown out the chaff.

In the latter year, on the contrary, the ground was plowed and pulverized in the same operation by a disk plow; the seed was sown with a mechanical seeder drawn by horses; the reaping, thrashing, and sacking of the wheat was done with the combined reaper and thrasher drawn by horses, and then the wheat was ready to haul to the granary.

HAYMAKING.

Hay is the next selection for comparison, the years being 1860 and 1894. When men mowed the grass with scythes, spread it and turned it over for drying with pitchforks, when they raked it into windrows with a hand rake, cocked it with a pitchfork, and baled it with a hand press, the time of human labor required per ton was 35½ hours; but when for this method was substituted a mower, a hay tedder, and a hayrake and hay gatherers and stackers drawn by horses, and a press operated by a horse, the time of human labor was reduced to 11 hours and 34 minutes, while the cost of human labor from the earlier to the later year was reduced from $3.06 to $1.29.

The more noticeable economy in haymaking is in the mowing and curing of the grass. In these two operations the time of human labor declined per ton from 11 hours to 1 hour and 39 minutes, while the cost of the human labor declined from 83⅓ cents to 16¼ cents.

The comparisons might be extended throughout many of the crops produced by the farmer, with a constantly recurring illustration of the saving of human labor and of the diminution of the cost of production by the dimunition of human labor. With regard to animal labor alone it often appears that an increased time is required in production, but where there is an increased cost it is principally due to the increased value of the labor of animals.

SAVING IN THE COST OF PRODUCING CROPS.

The potential saving in the cost of human labor on account of improved implements, machines, and processes, at the rate per bushel or ton, as the case may be, has been computed for seven of the principal crops of 1899; the comparison is between the old-time methods of production, in which hand labor was assisted only by the comparatively rude and inefficient implements of the day and the present time, when hand labor has not only the assistance of highly efficient and perfected implements and machines, but has been considerably displaced by them. The saving in the cost of human labor in cents, per unit of product, permits a very forcible statement of its equivalent in money by means of a computation consisting of the multiplication of the saving per unit into the crop of 1899. The result expresses the potential labor saving in the production of seven crops of that year, and is not an aggregate of the saving of human labor in the cost of producing the crops for all of the years between the earlier and the later ones, during which time this economizing and displacement of human labor has taken place. In the case of the crop of corn, the money measure of the saving of human labor required to produce it in 1899 in the most available economic manner, as compared with its production in the old-time manner, was $523,276,642; wheat, $79,194,867; oats, $52,866,200; rye, $1,408,950; barley, $7,323,480; white potatoes, $7,366,820; hay, $10,034,868.

The total potential saving in the cost of human labor for these seven crops of 1899, owing to the possible utilization of the implements, machines, and methods of the present time, in place of the old-time manner of production, reaches the stupendous amount of $681,471,827 for this one year.

CONCLUSION.

It would be idle to claim that the progress of the agriculture of the United States and its evolution from the primitive scope and conditions in which it was found by the settlers who came from Europe have been set forth adequately, even in its important topics and details, in the foregoing pages, but perhaps enough has been presented to explain in their main features the causes and opportunities which in combination have led to an agricultural production actually too great to be grasped by the human mind.

As great as has been the growth of manufactures, mining, the fisheries, and trade and transportation, all of which tend to draw population from agriculture, yet more than one-third of the population of the country is engaged in agriculture or dependent upon agriculturists. This element in our population has proved to be a strong one. It has been conservative with regard to those things that experience has demonstrated to be good. It has been an industrial element upon which all other elements of the population have needed to depend as the cornerstone of the social and industrial structure.

The agricultural element is the one independent element in our society. Let whatever betide that may, this element has a degree of independence in subsistence and in living that no other element has, and still, as in the past, remains the chief mainstay of the nation.

SOIL INVESTIGATIONS IN THE UNITED STATES.

By Milton Whitney,
Chief of Division of Soils.

INFLUENCE OF TRANSPORTATION FACILITIES ON POPULATION AND FARM CROPS.

The nineteenth century opened with the civilized communities of the United States confined principally to the Atlantic seaboard and along the most important rivers, where easy water communication could be utilized in transporting farm products to the cities and foreign countries. This necessarily restricted farming to what are now called the Atlantic Coast and Gulf States, but it is an interesting fact that this area contains a greater variety of soils, ranging from the most fertile limestone valleys to the most barren sands and clays, than can be found in an area of equal size in any of the more recently settled portions of the country. The most important cities of that period were situated at the fall line of the rivers for the advantages of water power in manufacturing and manipulating farm products on one side of the city, and of water transportation to various markets on the other side. About 1836 the Chesapeake and Ohio Canal was completed for a distance of about 65 miles from Washington, D. C., thereby opening up a large territory by placing it in easy communication with the coast. About this time also the Erie and other canals were completed, and the possibilities of extension began to be considered. With the wide introduction of railroads, between 1850 and 1870, the possibilities of general and close connection between the products of Western and inland soils and the Eastern cities and foreign countries became fully apparent.

The gold discoveries of California in 1849 stimulated the interest and led to the construction of the transcontinental lines of railways, which have brought the Pacific coast into closer touch with the Atlantic seaboard than Ohio and Kentucky were at the beginning of the century; while the effect of steamship transportation furnishing rapid, sure, and safe delivery of agricultural products to foreign countries at very reduced prices has been to open up the markets of the world and make it possible to dispose of the vast quantities of goods produced in excess of the requirements of domestic markets.

EARLY WESTWARD MOVEMENT IN SEARCH OF NEW SOILS.

At the beginning of the century (and even before) it was noticed that the soils, particularly of Virginia and Maryland, were losing in fertility. With this deterioration of the soils and the effect of competition from the rapidly increasing population, together with the naturally restless spirit of a certain class among the settlers, a westward movement set in along the fertile limestone areas of western Maryland, the Valley of Virginia, and the limestone areas (blue-grass region) of Kentucky and Ohio. It speaks wonders for the intelligent appreciation of the natural fertility of the soil by the pioneers of those days that these areas were first settled, which are even now considered the most fertile and most valuable for general agricultural purposes. The leading politicians and statesmen of the time, imbued with the European ideas of intensive cultivation, opposed this extension and discouraged the tendency to diffusion, which was becoming so apparent. There were political reasons which weighed even more with them, but it is an interesting fact that these ideas were held by such men at this period. The old Maryland and Virginia families, who, as a rule, were devoted to their homes, contributed but slightly to this extension, only a small proportion of the population of those States being adventurous and restless enough to move West and there open up wild and difficultly accessible tracts.

The products of the soils of Kentucky, Tennessee, and Ohio, which began to take a place in the commercial world early in the present century, were shipped by water to New Orleans.

EFFECT OF RAILROAD EXTENSION ON CROPS AND VALUES.

The Western extension of the railroad, which opened up the virgin prairie lands of the West, where the cost of production is much less than in the Eastern States, and where farming operations are of enormous proportions, has had the effect of forcing specialization upon the Eastern farmers. Some of the most worthless soils have become of great value for certain crops, while some of the most fertile soils have depreciated in value. Other soils have been abandoned from inability to compete with the Western prairies, and the present lack of any special crop or interest peculiarly adapted to them.

The influence of the railroads in providing easy, rapid, and cheap transportation from the fertile prairies of the West and the extraordinarily rapid settlement of the country have been far more potent in the present distribution of farm crops and land values than the exhaustion of the Eastern soils through continuous croppings of nearly three centuries.

EARLY USE OF FERTILIZERS.

As before stated, the deterioration of the lands in the older States was giving no little concern both to statesmen and land owners at the beginning of the present century. It was very generally believed, and is even yet held, that the continuous cultivation of tobacco was very seriously impoverishing the soil. This must have been alarming, indeed, as tobacco had been the most important crop of the colonies, yielding a large part of the revenues, and even passing as currency by legislative enactment for nearly two centuries.

The ideas at that time regarding the requirements of plants and the office of the soil in plant production were exceedingly crude. It had long been a matter of dispute whether the soil furnished any essential ingredients of plants. While these matters did not begin to be clearly understood until Liebig's remarkable generalization of the mineral theory of plant growth in 1840, in the elaboration of which our modern theory and practice of fertilization have been built, it is a mistaken impression that fertilizers were not used before Liebig's time for the increase of crops and the maintenance of soil fertility. On the contrary, they had been used for a long time. The excrement of animals had been used from the earliest historic times. It is stated that the Indians put fish in hills of corn when planting in order to increase the yield, and they taught our earliest settlers to do likewise. Guano had been used from the very earliest times by the Peruvians, and its richness and wonderful effects were observed by Humboldt in 1806.

Lime, plaster, and marl had long been used on the soil, and were earnestly advocated by agricultural writers. In 1817 superphosphates were manufactured for the first time in England, and other substances had been tried with varying success for restoring and maintaining the fertility of the land.

DEVELOPMENT OF THE USE OF FERTILIZERS.

It was not, however, until Liebig's work on the mineral theory of plant growth that the exact requirements of the plants and the important office of the soil began to be fully appreciated. The vehement discussions to which Liebig's work gave rise led to a critical study of the requirements of plants and the availability of soil constituents by Boussingault, Lawes and Gilbert, and others. Between 1865 and 1873 the foreign experiment stations took up the matter and made a critical study, by means of water-culture and sand-culture experiments, on the exact requirements of plants for mineral nutrients. The results of this work have laid the foundation for the development of the present enormous industry of the manufacture and sale of commercial fertilizers in this country.

In 1840 the first ship load of Peruvian guano was sent to England for use as a fertilizer on lands. In 1842 a company was organized and the trade in this substance was regularly commenced. Guano quickly spread in popular favor in this country, and it came to be used very extensively upon the tobacco soils of Virginia and Maryland. After twenty or thirty years of continual usage, it was very generally believed that the tobacco lands had been injured by its use. The guano, it was supposed, stimulated the plant to such an extent that other food materials in the soil were used up faster than they were made available through the natural process of weathering, and, the plants suffered in consequence.

The Peruvian guano was used principally for its ammonia. The West Indian guanos, which came in later, were found to be rich in phosphates and better adapted and safer for some crops than the Peruvian.

Ground bones and boneblack were almost the only other sources of phosphoric acid until 1867, when the South Carolina rock phosphates were introduced. In this year six tons of this rock phosphate were put upon the market. The mining of this South Carolina product rapidly increased until the year of largest production in 1889, when 541,645 tons were produced. The Florida phosphates were developed as a commercial product about this time, and still later the extensive deposits in Tennessee were discovered and mined.

Wood ashes had been used for a long time with remarkable success, but without the knowledge that the success depended largely upon their potash content. They were indeed the principal source of supply of this element until the Stassfurt potash salts were introduced about the year 1860; since this time the Stassfurt salts have been the principal and almost the only source of supply of potash in concentrated forms for crops.

In 1860, in the report upon the geology of New Jersey, Cook called attention to the wonderful richness and effect on the soils of that State of the greensand marls due to the potash and especially the phosphoric acid content. Ruffin likewise called attention to the marls of Virginia, and taught some valuable lessons on the manipulation and care of fertilizers.

The trade in nitrate of soda began between 1830 and 1840. Animal excrement and fish had long been used, as already stated; and these, with the refuse from the large modern slaughterhouses, together with sulphate of ammonia from the gas works, are still the main sources of supply of nitrogen for crops.

After the early work of Johnson, who had been a student of Liebig, the great commercial value of fertilizer analysis and control became apparent, and, after the practical results attained by the German experiment stations recently established, it is no wonder that on the establishment of the first experiment station in this country, at Middletown, Conn., and in the other stations, which rapidly organized, the subject of fertilizer control became the most popular and really the most important subject taken up. The early investigations of the German experiment stations between 1865 and 1873 in water and sand culture and the subsequent pot and field experiments determined the essential elements of plant food likely to be deficient in available form in the soil, and these have been mined or manufactured in various forms; but the rule for the mixing of these for various crops or for different soils has been and is yet very largely empirical.

Many very elaborately planned and well executed field experiments with fertilizers on various soils and with many crops have been carried on in this country during the past twenty-five years, but, owing to the varying character of the seasons and to other conditions not clearly understood, the results have been conflicting and impossible to interpret.

The Cornell experiment station carried on some of the earliest of these field investigations, then the Massachusetts station, the New Jersey station, and many others. Atwater carried out a most elaborate series of field experiments with fertilizers for a number of years through the cooperation of farmers in many of the States. McBryde also carried on a most interesting series in Tennessee and another in South Carolina. Atwater found that the requirement of any particular crop varies greatly, not only with the locality, but with the climatic conditions. Results on one soil were likely to be entirely reversed on another, even with the same crop, and on the same soil from one season to another, and this has been the general experience in nearly all such work.

CHEMICAL INVESTIGATION OF SOILS.

The discussion of the development of the use of fertilizers has preceded that of the chemical investigation of soils, because, although the latter subject logically comes first, the use of fertilizers has been developed more as the result of practical experience and deductive reasoning from other scientific investigations than as a direct result of the chemical analysis of soils.

It is needless to say that the original expectations and claims of the Liebig school that a chemical analysis of soils and plants would give definite indication of the requirements of a particular soil for any plant have not been realized. There have been too many other factors influencing plant growth, which have not been considered or which have not been clearly understood by agricultural chemists. For example, very little is known about the constitution of silicates or the form in which the plant food is held in the soil, or the nature of the influences affecting the solubility of these substances. Furthermore, the influence on plant development of the various elements of meteorology or their resultant, comprised in the term climatology, are no better understood. Nevertheless, the investigations have added greatly to the store of human knowledge and have given a mass of detail which will undoubtedly form a valuable basis for further generalizations and further lines of research.

GROWTH OF SYSTEMATIC ANALYSIS OF SOILS.

As early as 1820 to 1830 various agricultural surveys were organized in several States, notably in Maine, Massachusetts, New York, and North Carolina, but one of the first official recognitions of the importance of soil analysis was in the establishment, by the legislature of Maryland in 1847, of the position of agricultural chemist for the State, who, among other duties, was required to spend one year in each of the districts and one month in each county and to visit each election district; also to analyze specimens of each variety of soil which might be brought to him or which he might find to exist. This work was continued in a modified form up to 1859, when the survey was discontinued. A number of reports were issued during this period, which, on account of crudeness of the methods of analysis employed, are only of historic interest so far as the analyses themselves are concerned.

In the year 1850 Dr. David Dale Owens, assisted by Dr. Robert Peters, began an extensive chemical examination of the soils of Kentucky in connection with the geological survey of that State. This is really the beginning of systematic work in the chemical analysis of soils in this country. In 1860 Hilgard published his report upon the geology and agriculture of the State of Mississippi, and in 1875 he commenced the series of investigations of the soils of California, which have been vigorously prosecuted ever since. In 1875, in connection with some of Hilgard's results, Johnson pointed out the doubtful utility of the ordinary chemical analysis of soils as an indication of the relation of the soil to plant growth, except in special and rather exceptional cases. He showed in a most forcible manner that an ordinary amount of fertilizer, though sufficient to make a difference between a good crop and a failure, could not be detected in the soil by the most refined chemical means, and he concluded, therefore, that the ordinary chemical analysis, giving only the gross amount of substances dissolved by a mineral acid, could give no true indication of the amount of food in the soil actually available to crops. This conclusion was substantiated by the fact that nearly all analyses by the methods then used indicated an amount of food material, even in the poorest soils, sufficient for many average crops. Notwithstanding Johnson's argument, the chemical work was continued by a few scientists. In 1879 the taking of the Tenth Census provided an opportunity for Hilgard and his colaborers to undertake a very remarkable and valuable series of investigations, including the chemical analyses of the soils of the cotton States, and for Killebrew to collect a large amount of valuable information in regard to tobacco soils of the United States. For forty years Hilgard has been an earnest advocate of the value of the chemical analysis of soils, although recognizing, to a certain extent at least, the influence of physical conditions.

In the Tenth Census, Hilgard, in an article prepared in 1879, summarizes the results of his long experience; but these are of the most general character and adapted only to the most general application.

EFFECT OF CHEMICAL RESEARCH ON SOIL PROBLEMS.

The application of chemical research to the problems of the alkali soils and waters of the arid West have been shown by Hilgard to be of very great economic value. Not only has the character of the waters been determined and settlers been warned of the use of waters containing too much salt for irrigation, but the character and location of the alkali salts in the soils themselves have been shown, and in the case of the worst form of black alkali (sodium carbonate) a remedial measure in the application of gypsum has been pointed out. Drainage has been advocated in all cases where careful use of water, thorough cultivation, and judicious cropping will not protect the crops.

The Alabama geological survey republished in modified form the results of the chemical work on the soils of that State which had been done for the Tenth Census. Since that time several of the other States, notably North Carolina and South Carolina, have likewise republished the census material in modified form. Several of the State geological surveys have investigated the chemical composition of the soils of their States. In 1895 Wheeler began and has since carried on an interesting line of investigation upon the acidity of the Rhode Island soils and the marked value of lime as a corrective for this.

The method of analysis employed by Owens and Hilgard, and which is still followed to a large extent, was to digest the soil for a considerable time with hot concentrated hydrochloric acid. When it became apparent that the results secured by this digestion did not clearly express the relative value of soils for crops, Grandeau's hypothesis was taken up and the amount of plant food contained in the organic matter of the soil was determined. More recently many modifications have been suggested in the use of dilute mineral and organic acids in the effort to find a solvent which will express more exactly the amount of available plant food in the soil. Owens recognized the advisability of this in the use of carbonated water in the digestion of some of his soils. Nothing wholly satisfactory as a method of analysis has yet been worked out.

Hilgard recognized, in his Mississippi work, that plants are often a sure indication of the agricultural value of a soil. In the Tenth Census he states:

> A soil naturally timbered with a large proportion of walnut, wild cherry, or, at the South, with the poplar or tulip trees, is at once selected as sure to be both productive and durable, especially if the trees are large. He (the farmer) knows well that the black and Spanish oaks frequent only "strong" soils, and that the admixture of hickory is a welcome addition, while the occurrence of the scarlet oak at once lowers the land in his estimation, and that of pine still more so. However much opposed to the cocklebur in his fields, he welcomes it as a sure sign of a good cotton soil, as much as though he had seen the latter itself growing for a series of years. * * * Taking for granted the soundness of the principle involved in judging the productiveness and the peculiarities of soils from their natural vegetation, and having gained a large array of additional data from personal observation

in the field, I have then sought to ascertain by close chemical and physical examination of the soils in their natural condition the causes that determined this natural selection on the part of certain species of trees and herbaceous plants, while at the same time observing closely the behavior of such soils under cultivation, their special adaptation, etc.

At the very close of the century the ideas brought out by the development of physical chemistry and the modern theory of solution give promise of many productive lines of investigation, which will undoubtedly greatly extend our knowledge of the chemistry of soils and explain many of the important problems of the distribution of crops and vegetation.

BACTERIOLOGICAL INVESTIGATION OF SOILS.

During the past twenty years bacteriologists have contributed a fund of information in regard to the bacteriological changes in the soil, especially upon the subjects of nitrification, denitrification, and the fixation of free nitrogen by the soils. These had been subjects of investigation by chemists for years, but it was not until the work of Pasteur, on the cause of fermentation and putrefaction in general, that the true basis of this soil work could be comprehended. Since then the subjects of nitrification and denitrification especially have been exhaustively studied. Quite recently the effect of leguminous plants with their tubercles and of cultures from these on the soil has received attention from the State agricultural experiment stations, notably the Alabama station.

This work has not only added to our general knowledge of the constitution and condition of the soils, but it has modified the practice of field culture, has enhanced the value of leguminous crops for green manuring, and is opening up the possibilities of pure bacterial cultures to increase nitrification and promote the fixation of the free nitrogen of the air by the soil. It has shown the most rational and economical methods of caring for and manipulating manures and composts and of applying green manures and nitrogenous fertilizers to the soil.

PHYSICAL CONDITIONS AND SOIL INVESTIGATIONS.

The physical conditions and peculiarities of soils have long been recognized as a potent factor in crop production. The early Romans used to plant their crops in wet soils on high ridges in order to secure sufficient drainage and early maturity. The sea island cotton planters, in the early part of the century, used the same method in a modified form to insure the maturity of the long staple crop within the limits of the growing season. More recently the practice of underdrainage with poles, stones, and tile-drains has supplanted this crude method and has given much more effective results.

UNDERDRAINAGE AND IRRIGATION.

About the middle of the present century the popular craze for underdrainage may be considered to have reached its maximum, but since then there has been enormous development in practice, particularly in the States of New York, Ohio, and Illinois. Shortly after this time the subject of subsoiling, to increase the water-holding capacity of the soil and as a protection against drought, became a popular fad. It was advocated by the agricultural press, and was much practiced in the Eastern States, but the general experience seemed to be that it was at least of doubtful utility on most soils for the staple crops, and did not compensate for the cost and great labor involved. In some cases, especially in horticultural work, it has been of the greatest value. It has recently been very successfully practiced in the soils of the semiarid regions of the West in providing a greater storage capacity for the soils against seasons of drought.

In 1847 the Mormons, driven out of Illinois, settled in Salt Lake Valley, Utah, and started the first systematic attempt at modern irrigation practiced in this country for the production of crops in arid soils. Since then this method of cultivation has been extended almost to the limit of the available water supply of the arid West. Volumes have been written upon the subject of irrigation and the wonderful development in the arid West; and the influence on the commercial world of the crops from the irrigated districts speaks for the success of this method of cultivation under these special conditions. Quite recently the Department of Agriculture has attacked the problems of seepage and alkali in the irrigation districts with the most gratifying success. The alkali soils are being mapped, the source of the alkali determined, the cause of the accumulation of the alkali salts shown, and the rational treatment of the lands to prevent injury and to reclaim abandoned lands pointed out.

TEMPERATURE AND MOISTURE OF SOILS.

Considerable attention has been given in the past twenty years to the study of the temperature of soils. The work was started in this country at the Houghton Farm in New York in 1882. It was taken up by the Geneva experiment station in 1883, by the North Carolina station in 1886, and by the Maine experiment station in 1889. Since then considerable work has been done by the experiment stations of Indiana, Michigan, and other States. A great amount of statistical data has been obtained and some few rather unimportant generalizations have been made, but the subject is extremely difficult and complicated, and much of the data has not yet been interpreted.

The North Carolina experiment station recognized the influence of moisture on the temperature of soils and the very much greater influence of the changing moisture content during the growing season than the normal differences in temperature. This subject was therefore taken up as of paramount importance. This moisture work was continued at the Maryland experiment station and later was considerably developed by the Department of Agriculture.

In the Department of Agriculture an electrical method of moisture determination has been devised, and a large amount of data collected and published showing the relation of some of the important types of soil to crops and the influence of soil moisture on the distribution of crop interests. It has been shown that this is a factor in climatology. It is believed that this work has been carried as far as is justifiable without a very wide extension of the work in the line of climatology, which circumstances have not warranted.

TEXTURE OF SOILS.

The mechanical composition, or texture, of soils was studied by Hilgard and many analyses were published by him in the report of the Tenth Census and in the bulletins of the California experiment station, but no general conclusions or principles were drawn from the work. In 1891 the Maryland experiment station developed the work, in cooperation with the Department of Agriculture, in the study of the soils of Maryland. In 1892 the Weather Bureau published a report of this work in a bulletin entitled "The physical properties of soils in their relation to crop production," in which it was shown that there was a relation between the texture of the soils and the crops and agricultural interests adapted to the land. This had been recognized to a certain extent in the specialization of the truck farming on the light sandy soils of the coastal plains, but these soil investigations showed that nearly all the soil types which differed in agricultural value and adaptation to crops differ also in texture and physical properties to an extent which might reasonably account for the existing conditions.

Since then the investigations of the Department of Agriculture of the truck soils of the Atlantic coast and of the soils of the principal tobacco districts, as well as other less complete lines of investigation, show very strikingly the influence of the texture and physical properties of soils on crop production. The commercial type and grade of tobacco and the adaptation to cigars, cigarettes, pipe smoking, chewing, or export, are dependent partly upon the climatic conditions and largely upon the texture of the soil.

SOIL MAPS.

Hilgard published an agricultural map of Mississippi in 1860 showing the distribution of the soils of the State. This was based principally upon the distribution of the native vegetation, especially upon the forest trees. Following out this idea, soil maps of all the cotton-producing States were published in connection with the Tenth Census. Much of this work has subsequently been republished in modified form by the several States and enlarged maps have been issued.

Many general reconnoissances have been made by State geological surveys and by the transcontinental surveys for railroads.

In 1892 the first soil map, based upon the texture and physical properties of soils, was issued by the World's Fair Commission of Maryland, in connection with the handbook of the State prepared at the Johns Hopkins University.

Quite recently the Department of Agriculture has undertaken the survey and mapping of the soils of some of the important agricultural districts of the country. The work is based entirely upon the differences in the texture of the soil as seen in the field, the distribution of vegetation, or such other evidences of the agricultural value as can be obtained in the field. While these field methods are quite independent of laboratory work in the actual preparation of the maps, chemical, physical, and geological laboratories are maintained to investigate the different types of soils, their origin, and exact chemical and physical composition. In 1899 about 720,000 acres were thus surveyed and mapped on a scale of one inch to the mile.

This work includes, as a most valuable feature, the investigation and mapping of alkali soils and the preparation of alkali maps. These later maps are based upon actual field determination of the soluble salts, to a depth of 6 feet or more, by an electrical method and by certain chemical field methods devised by the Department of Agriculture for this work.

IMPORTANT SOIL INVESTIGATIONS AND THEIR UTILITY.

The most important lines of investigation and their probable utility may be briefly summarized. The most pressing need is a more rational and more complete theory upon which to base our system of fertilization. It seems hopeless to expect much from the indiscriminate chemical analyses of soils by the methods at present in use to indicate the actual needs of a soil, save only in exceptional cases. From the preparation of detailed soil maps and the study of large and uniform types of soil, with their slight but significant variations in chemical composition and physical properties, compared with other types having well-marked differences, much may doubtless be learned. The study of the solubility of the soil constituents, the equilibrium between the resulting components, and the disturbances of the equilibrium by the addition of salts and fertilizers of different kinds, together with the absorptive phenomena and diffusion and leaching, is extremely important in view of their bearing upon the needs and the effect of fertilizers. Then, the effect of long-continued cropping, the effect of changing climatic conditions on the crops, the development of the crop itself, and the experience of farmers, if thoroughly investigated, will give suggestive hints of the soil conditions.

The physical investigation of the texture and structure of soils and of the important changes which are known to result from the physical forces acting between the soil grains in all conditions, from a loose loam to a puddled and impervious silt or clay; and the effect on these physical forces and physical properties of fertilizers, cropping, and cultivation, will unquestionably be of economic value.

The relation of soils to moisture and the variation of soil moisture throughout the season, in connection with temperature, humidity, and movement of the air, and the duration and intensity of the sunshine as an essential feature of climatology should be developed to the fullest extent, as they unquestionably play a very important part in the development and distribution of crops. The investigations of the Division of Soils indicate that the time has come when the relation between these factors can be determined and their relation to plant growth can be intelligently studied.

Probably the most important immediate results of practical utility to be derived from these soil investigations are the mapping of large areas in important agricultural districts. In the irrigation districts these investigations point out any source of alkali which is to be feared, the cause of the accumulation, and give a basis for the intelligent underdrainage when necessary to remove the salts and seepage waters. In all cases the maps show the various types of soils, and the reports accompanying them explain the differences in these soils, so far as possible, and describe their characteristics. The greatest value of these maps will be in the possibility of intelligent specialization. When a light loam is seen adjoining a heavier loam or clay the methods of cultivation or cropping should not be alike, and will not be when the farmers realize the importance of the differences in the properties of the soils. It is generally a waste of energy to attempt thus to compete, or use the same methods, or even to grow the same crops oftentime on soils of such different texture. The safest and altogether most practical thing is to recognize the differences in the soils and the peculiarities of each; use each for the particular crop or class of crops best suited to the conditions; then attempt to improve each by the controlling factors, which are quite sure to be revealed in the experience of changing climatic conditions and the development of crops in the course of two or three years. The development of plants is a sure and safe guide generally to an experienced person as to the condition of the soil. This specialization is unquestionably developing in this country as a result of competition and of social conditions, and reliable and detailed soil maps will be the best possible basis for this purpose.

PROGRESS OF ECONOMIC AND SCIENTIFIC AGROSTOLOGY.

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Agrostologist.

DEFINITION OF AGROSTOLOGY.

The science of agrostology, strictly speaking, relates only to the true grasses, and an agrostologist is one who has made a special study of these plants; but in the present paper the term is used in a broad sense, and embraces not only the true grasses, but all other pasture and fodder plants. In this broad sense the subject becomes one of the greatest economic importance, in which every citizen of the United States is more or less directly interested; but only its more salient features can be considered in this paper, many interesting minor facts being of necessity wholly omitted. In the present treatment of the subject it has been found convenient to divide it into two parts: First, economic, or applied, agrostology; second, scientific, or systematic, agrostology.

ECONOMIC, OR APPLIED, AGROSTOLOGY.

CONDITIONS PRIOR TO THE BEGINNING OF THE CENTURY.

Prior to 1800 practically nothing had been done in this country in the cultivation of grasses and forage crops. There were comparatively few farms, and the food supply of cattle and horses was chiefly furnished by the natural growth of the indigenous grasses. The great grazing regions of the West were then unknown, and the almost boundless capacity of this country to support cattle of all kinds was not even suspected. The best known hay and pasture grasses were not unknown in those days; timothy, redtop, tall meadow oat grass, orchard grass, crested dog's-tail, and meadow foxtail had been frequently mentioned by agricultural writers for fifty years or more. Schreber, in his great work on grasses, published in 1769, minutely describes and illustrates all the species just mentioned, besides many others, including the now popular smooth brome grass; he notes, too, the special characteristics of each grass, the kind of soil to which it is adapted, and its agricultural value. It is a curious fact, noted also by Schreber, that timothy, a native of Europe, was introduced into cultivation in Europe through seed secured from this country.

CONDITIONS DURING SEVENTY-FIVE YEARS OF THE CENTURY.

Although at the beginning of the present century the list of forage grasses contained many names, very few had been taken up by American farmers; in fact, it does not appear that during the first half of the century any marked progress had been made in the way of cultivating new or improved varieties. A few of the leguminous plants began to attract attention, but the farmers throughout the New England and Middle States were mostly content with timothy and redtop or timothy and clover and apparently cared for little else. The value of clovers and leguminous crops generally for improving the soil was recognized by the more progressive farmers, and improved farming methods were beginning to be practiced by the more intelligent. In the South little attention was paid to grasses, and the planters imported most of their hay supply from the North. The common cattle found sustenance in the natural herbage, and crab grass, the poor man's hay, was as common then as it is now. In the West no attention whatever was paid to the cultivation of forage crops, the rich and abundant growth of grasses which everywhere covered the country at that time seeming to offer an inexhaustible supply for all grazing animals.

FIG. 5.—Big blue stem (*Andropogon provincialis*): *a*, a pair of spikelets; *b*, first empty glume; *c*, second empty glume; *d*, third glume; *e*, fourth, or flowering, glume; *f*, palea; *g*, lodicules.

"Grasses for the South," by Rev. C. W. Howard, is the subject of a valuable paper published in the Agricultural Report of the Patent Office for 1860. Thirty-one varieties of grasses and forage plants suited to the South are described, and in the same paper fifteen economic grasses of Texas are described by Mr. G. Lincecum. The laying down of meadows and pastures and the management of grass lands are also fully discussed.

In 1869 the Superintendent of Gardens and Grounds of the Department of Agriculture, Mr. William Saunders, started a grass garden upon the Department grounds, in which fifty-one varieties of grasses and forage plants were cultivated. The results obtained the first season were published in the Report of the Commissioner of Agriculture for

1869. Further notes in regard to these experiments by Mr. Saunders appear in the Report of the Commissioner for 1870, and in the same report there is a most interesting account of the grasses of the plains and of the eastern slope of the Rocky Mountains. Several of the more important species, including big blue stem, the various gramas, bromes, and fescues are described, and their apparent value commented on. It is claimed that the big blue stem (*Andropogon provincialis*, fig. 5), together with the little blue stem (*Andropogon scoparius*), formed 60 per cent of the grass flora in the Missouri River region and 26 per cent of the grasses in the Rocky Mountain region. The paper in the report of 1870 appears to be the first that treated exclusively of the grasses of the region mentioned from an economic standpoint, and the grasses then noted as being of most value are those attracting most attention to-day.

GRASS AND FORAGE PLANT INVESTIGATIONS.

As early as 1878 Dr. Vasey, the Botanist of the Department of Agriculture, published in the reports of the Commissioner illustrated papers on the grasses and forage plants of the country, and during the entire period of his service, from 1872 to 1893, he continued to give much attention to the subject and to devote much effort to promoting the interests of economic agrostology.

The unwise management and overstocking of the rich grazing lands of the West have forced upon the farmers of that section the necessity of giving attention to the cultivation of forage crops or at least making an effort to preserve those grasses which have not already been destroyed. The cattle ranges of the Southwest were the earliest to suffer from overstocking, and it was to this region that the Department of Agriculture first directed its attention along lines of grass and forage-plant investigations. In 1886 the Botanist of the Department drew attention to the enormous loss of cattle in the Southwest through overstocking of the ranges and lack of protection from storms in winter. In Bulletin No. 3 of the Division of Botany, published early in 1887, there was presented a report on certain grasses and forage plants for cultivation in the South and Southwest. In this report we find lengthy accounts of carpet grass, hairy-flowered Paspalum, guinea grass, crab grass, Texas millet, etc. This was the first work of the kind published by the Department, and owing to the very complete and practical treatment of the subject, it at once excited a good deal of interest among the farmers and ranchmen of the region it was designed to cover; and it set them to thinking about improving their hay lands and pastures. During the year 1887 the Botanist carried on field investigations through western Texas, New Mexico, Arizona, Nevada, and Utah, the results of which were published in Bulletin No. 6 of the Division of Botany. An enumeration of the grasses of Texas was published in 1890 in Vol. II of the "Contributions from the U. S. National Herbarium." The most comprehensive economic work published by the Department on grasses and forage plants was issued in 1889 under the general title of the "Grasses and forage plants of the United States, by Dr. George Vasey, with an appendix, giving the chemical composition of grasses, by Clifford Richardson." This work contains 114 full-page plates, illustrating the various grasses and forage plants described, and is essentially a revised and enlarged edition of a similar report published in 1884, under the title "Agricultural grasses of the United States."

During the year 1888 the results of the investigations in the arid regions the two previous seasons bore fruit in the way of securing from Congress an appropriation for the establishment of a grass experiment station at Garden City, Kans. This was the first effort of the kind receiving governmental support. The tract selected for this station contained 240 acres, and experiments were carried on there for five years, from 1888 to 1893. The results accomplished were on the whole satisfactory, and were given in detail in the Reports of the Secretary of Agriculture for 1891, 1892, and 1893.

There have been a number of works on grasses and forage plants published by private enterprise during the last half of the present century. These works, being widely read, have played no insignificant part in diffusing a knowledge of the plants of which they treat, and doubtless they have had a direct influence in improving American agriculture. Among the more important of these publications, the following may be mentioned: "The grasses of Wisconsin," by Dr. I. A. Lapham; "The grasses and forage plants of Tennessee," by J. B. Killebrew, published in 1878; "Grasses and forage plants," by C. L. Flint, an illustrated work of nearly 400 pages; "A handbook of the grasses of Great Britain and America," by J. Henderson; "Farmer's book of grasses and other forage plants for the Southern United States," by D. L. Phares; "Grasses and their culture," by J. S. Gould, 212 pages and 74 plates, published in the Report of the New York Agricultural Society for 1869; and the first volume of Beal's "Grasses of North America," which includes chapters on the physiology, composition, selection, improving, and cultivation of grasses and clovers.

During the past twenty years great progress has been made in the introduction of new forage plants and improved methods of forage production and feeding. Probably the greatest advance has been made in the use of silage and soiling crops and in the increased production of leguminous plants. The agricultural press of the country, the numerous publications of the State experiment stations, and the various bulletins and reports issued by the Department of Agriculture, have all helped to bring about these improved conditions, until to-day our country leads all others in the art of applied agrostology.

ESTABLISHMENT AND WORK OF THE DIVISION OF AGROSTOLOGY.

A new impetus was given to the work of applied agrostology in the United States by the establishment, in 1895, of a division in the

Department of Agriculture devoted exclusively to the investigation of grasses and forage plants. The recommendation for the establishment of such a division was made by the Secretary of Agriculture in his Annual Report to the President for 1894, as follows:

> The forage interests in the United States are vast in value. Seventy million tons of hay are cut and cured each summer. This crop is taken from 50,000,000 acres of land. Each year's hay crop is estimated to be worth $600,000,000. No accurate means have been found for ascertaining the cash value of grasses upon pasture and other lands that are grazed. It is known, however, that these lands support and fatten vast herds of cattle, sheep, and horses. In 1890 such ranges in the United States fed 14,059,030 head of domestic animals. As these millions of animals subsist largely upon native grasses and other forage plants, the magnitude of these figures elucidates the vital necessity of securing, if possible, new and better forage plants in this country. * * * Therefore * * * it is proposed to create a new division in this Department [Agriculture], as provided in the estimates submitted herewith, to be called "The Division of Agrostology." * * * If the hay production in the United States, as a result of this effort in behalf of agrostology, is raised only 1 per cent, it is equal to an increase of $6,000,000 per year in the value of this single farm product.

The law passed by Congress, in accordance with the above recommendation, establishing the Division of Agrostology, provided for field and laboratory investigations relating to the natural history, geographical distribution, and uses of the various grasses and forage plants and their adaptability to special soils and climates; the establishment and maintenance of experimental grass stations; the collection of seeds, roots, and specimens for experimental cultivation and distribution; the preparation of drawings and illustrations for special purposes, as well as illustrated circulars of information, bulletins, and monographic works on the forage plants and grasses of North America. This law authorized work along technical, or systematic, lines, as well as lines of applied, or economic, agrostology. It made possible greater concentration of purpose and more systematic effort than had before existed, and gave due recognition to an agricultural subject of the greatest importance to the entire country. It afforded means for a wider distribution of the knowledge already gained by the Department and the State experiment stations, and rendered possible the undertaking of new lines of research and closer cooperation with experiment stations and individuals in future investigations. Immediately upon the establishment of this new Division, plans were laid for a vigorous and systematic prosecution of the work along the lines indicated in the act of Congress. In a country of such vast extent and varied character as the United States, there were necessarily many problems relating to the forage supply that demanded the attention of the Agrostologist, and the range of investigations, embracing both purely botanical work and the more practical questions relating to methods of cultivation, adaptation of varieties to local conditions, and the factors governing the forage supply of the different sections of the country, opened a broad and interesting field of labor.

INVESTIGATIONS IN THE WEST.—One of the first subjects to engage the attention of the Agrostologist was the cause of the depletion of the Western stock ranges and the best means of restoring the grasses which had been destroyed by overstocking. Preliminary work was at once undertaken through studies in the field and by the establishment of grass gardens at Washington, D. C., and elsewhere, and by instituting cooperative work with individuals and State experiment stations. During these investigations the more important regions concerned were visited, leading stockmen and farmers were consulted, and data secured concerning soil and climatic conditions relating to forage problems, distribution and value of the native grasses and forage plants, the existing conditions of the stock ranges, the best methods of growing grasses and forage crops, and other questions pertaining to forage production. It soon became evident that one of the most effective means for ascertaining the best methods of restoring or improving the ranges would be the establishment of stations at typical points, where tests could be made with drought-resisting grasses and forage crops, and where general methods of range improvement could be practiced. Such stations were established in 1898 in Texas—one at Abilene and one at Channing. Another station was carried on at Knoxville, Tenn., in cooperation with the experiment station of that State, and early in 1899 arrangements for cooperative work with the experiment station of South Dakota were effected, and a station established at Highmore. Other station work has been done in cooperation with Western railroads at points in eastern Washington.

The field investigations carried on by the Division in the West have been in the States of Montana, Wyoming, Colorado, the Dakotas, Nebraska, Iowa, and Texas. From this work in the West, which is still being carried on, the following publications have directly resulted: "Grasses and forage plants of the Rocky Mountain region," Bulletin No. 5; "Grasses and forage plants of the Dakotas," Bulletin No. 6; "Grasses and forage plants of Iowa, Nebraska, and Colorado," Bulletin No. 9; "Grasses and forage plants of Central Texas," Bulletin No. 10; "Grasses and forage plants and forage conditions of the Eastern Rocky Mountain region," Bulletin No. 12; "The Red Desert of Wyoming and its forage resources," Bulletin No. 13; "Grazing problems in the Southwest and how to meet them," Bulletin No. 16, and Circulars Nos. 21 and 23, the former being the first report on the experiments at Highmore, and the latter dealing with the results of the work at Abilene.

GRAZING AND FORAGE PROBLEMS IN THE SOUTH.—The grazing and forage problems in the South are of great importance. Keen competition is forcing the planters to adopt more diversified systems of agriculture. Four hundred species of grasses occur in the Southern States, and there are broad areas in these States which may profitably be devoted to meadows and pastures. While investigations have been going on in the West, a study of those grasses most likely to succeed and at the same time meet the needs of stock raisers and dairymen in the South has been made a feature of the work of the Division, particular attention having been given to the native forage plants and the best methods to be employed in maintaining or improving the existing pastures and forage supplies. In cooperation with the experiment station at Knoxville, Tenn., already referred to, trial cultivation of many varieties of grasses and other fodder plants has been made. Field work has been carried on in the States of Mississippi, Louisiana, Alabama, Georgia, Florida, North Carolina, and South Carolina, and a large amount of material of both botanical and practical interest has been gathered by direct observation or through correspondence. Several bulletins bearing upon this work have been published. The first bulletin issued by the Division was "Notes on the grasses and forage plants of the Southeastern States," and the following is taken from the introduction to this bulletin:

> Very few plants are widely cultivated in the South for hay or pasturage, the farmer relying for the most part upon the wild grasses. These may be roughly divided into two classes, the first comprising introduced grasses, mostly annuals, which spring up on cultivated land after the regular crops have been removed; the second, native grasses, the majority perennials, which make the bulk of th pasturage. Of the first class, by far the most important, is crab grass (*Panicum sanguinale*), which forms a great part of the volunteer hay crop of the South Atlantic and Gulf States. With it are often associated crowfoot or barn grass (*Eleusine indica*), little crowfoot (*Dactyloctenium ægyptiacum*), pigeon grass (*Setaria glauca*), and, in the far South, spur grass (*Cenchrus echinatus*), and Mexican clover (*Richardsonia scabra*). Of the native, perennial grasses, perhaps the most important belong to the genus *Paspalum*, Louisiana grass (*Paspalum platycaule*) being the most common and best known. *Panicum serotinum* is also a valuable pasture grass over extensive areas. The broom sedges (*Andropogon* species), early in the season, make the bulk of the grazing on thin, dry soils. Three other widely known forage plants, belonging to neither of these classes, must be mentioned. Johnson grass, dreaded as a weed, yet esteemed as a forage plant, is an introduced perennial grass, highly valued for hay. Japan clover (*Lespedeza striata*) is perhaps the most valuable pasture maker, for the largest area, in the Southern States, while both for hay and for grazing Bermuda is king among grasses throughout the South.

Other publications relating to the work done in the South are "Forage plants and forage resources of the Gulf States," Bulletin No. 15, published in 1896; and "Southern forage plants," Farmers' Bulletin No. 102, published in 1899.

Investigations on the Pacific Slope.—The grasses and forage plants of the great region west of the Rocky Mountains, constituting the Pacific slope, have from time to time received some attention from the Department of Agriculture, but the first systematic work of investigating the plants of that region was begun in 1898, when the Agrostologist visited the more important localities, noting the physical conditions of the soil and natural forage resources. Throughout the drier sections east of the Cascades the capacity of the cattle ranges has been much reduced through drought and overstocking and the forage problems there are very similar to those in western Texas and Wyoming, and can be met by similar methods. Experimental work with grasses and forage plants was begun in 1898 in cooperation with the Northern Pacific Railroad and the Oregon Railroad and Navigation Company. The preliminary report on this work has been published as Circular No. 22 of the Division of Agrostology.

SPECIAL INVESTIGATIONS.—Aside from the general work of investigation of grasses in their relation to the forage supply of the country, special studies have been made on individual species, such as cowpeas, sorghum, millets, saltbushes, vetches, etc., concerning which special papers or reports have been issued by the Department. Investigations have also been carried on relative to the adaptability of grasses to special uses, such as the formation of lawns, the binding of soils subject to wash, and the holding of drifting sands. Careful studies have been made of the grasses used in various parts of the country for lawns, and the results of this work were published under the title of "Lawns and lawn making" in the Yearbook of the Department for 1897. The question of texture and color, so important in the making of a perfect lawn, were discussed in that paper, and illustrations introduced showing diversity of texture between several varieties of grasses which have been used as lawn grasses. In the United States there are long stretches of country bordering the Atlantic and Pacific coasts, and even along the shores of the Great Lakes, which are covered with drifting sands. These shifting sands are not confined to the shores of these great bodies of water, but frequently occur along the river banks and at various points in the interior of the country. In some cases the drifting of these sands is a serious menace to profitable agriculture, and along the coasts and rivers there is often danger to navigation, resulting from the shifting of large bodies of sand by the winds or waves. A few grasses have been found which may be utilized in effectually binding these shifting and destructive sands. The results of the discoveries and investigations made along these lines were published in the Yearbook of the Department for 1898 in an illustrated article on "Sand-binding grasses." One of the most recent discoveries of the Division in the way of sand-binding grasses is the seaside blue grass (*Poa macrantha*), which grows in the sands along the Pacific coast of Oregon and Washington, where it is often seen covering the summits of the highest dunes. It is an excellent sand binder, and possesses the advantage over beach grass in having more tender leaves and stems, which render it of value for grazing. It has the habit of sending out slender lateral branches, which, lying prostrate on the sand, extend 4 to 6 feet or more from the parent stock, and as these readily develop roots at the joints, the grass is rapidly propagated over considerable areas. If available for cultivation in the interior, seaside blue grass will prove a most valuable acquisition for cultivation in very sandy soils. The important subject of forage plants for cultivation on alkali soils is discussed in a paper from the Division in the Yearbook of the Department for the same year (1898), and in the Yearbook for 1895 is a paper on the "Grasses of salt marshes," the result of a previous year's investigation of the marshes along the coasts.

SOME VALUABLE GRASSES AND FORAGE PLANTS.—Some of the grasses and forage plants which the Division of Agrostology has recommended or to which special prominence has been given in its experimental work on account of their value for agricultural and other purposes are here given, as follows:

Blue grasses.—The blue grasses, of which Kentucky blue grass (*Poa pratensis*) may be considered the type, are among the most valuable species for pasturage, and some of them are unexcelled for hay. Kentucky blue grass is useful for both purposes, and is one of the most widely distributed species of the genus. In the United States it ranges from Maine to the Gulf, westward to the Pacific Ocean, and northward to Alaska. Some of the forms present qualities of unusual excellence, and the Division is giving attention to the selection of these for improving our forage supply. In the Rocky Mountain region are many species of Poa; a few of these the Division has experimented with to some extent, and so far quite satisfactory results have been secured, Wyoming blue grass (*Poa wheeleri*, fig. 6) being found one of the best. Its habit of growth is not unlike that of Kentucky blue grass, but it is probably much better able to survive long periods of drought than is that species. Smooth bunch grass (*Poa lævigata*) is another species of the blue-grass class common in the Rocky Mountain region. Mutton grass (*Poa fendleriana*) is one of the best grasses of the mountain

FIG. 6.—Wyoming blue grass (*Poa wheeleri*): *a*, empty glumes; *b*, *c*, florets.

ranges of New Mexico and Arizona. Nevada blue grass (*Poa nevadensis*) is a fine variety occurring in the Rocky Mountain regions of Montana and Colorado, some forms of it extending westward to the Cascades. It promises to be a very productive hay grass, and trials are being made with it having that in view. Sand blue grass (*Poa leckenbyi*) is a newly discovered species of eastern Washington, and is remarkable in growing in almost pure sand under conditions where the well-known Eastern grasses would fail entirely. It is hoped that this grass will prove to be not only a good sand binder but a good grass for very sandy soils and sandy areas in which other crops have failed. It is undoubtedly an excellent sand-binding species, and if it finally proves successful in the interior it will serve the double purpose of holding drifting sands and furnishing excellent forage.

FIG. 7.—Western wheat grass (*Agropyron spicatum*): *a*, empty glumes; *b*, florets.

Lyme grasses.—The lyme grasses present a number of varieties of special interest, and seeds have been collected of several of them. In some sections, Canadian lyme grass, or a form referable to that species, promises to be a most productive hay grass. It has been tried by the Division in Texas and at the stations in the Northwest. Woodland lyme grass (*Elymus glaucus*) is a common grass in Montana, Washington, and Oregon, and promises to be of some agricultural value. Giant lyme grass (*Elymus condensatus*) is a tall, rank-growing species of the Pacific slope, extending eastward to Montana. It is one of the dry-land grasses, and may prove of considerable value for hay or grazing in the drier regions of the Northwest. Yellow lyme grass (*Elymus flavescens*) and small sand lyme grass (*Elymus arenicolus*) are species of Oregon and Washington which are excellent natural sand binders. Along the Columbia

River the spontaneous growth of the sand lyme grass has in many cases effectually checked the drifting of the sands which are blown out from the river bed. Both of these species deserve careful consideration by those who are endeavoring to prevent the blowing of destructive sands.

Wheat grasses.—The wheat grasses are characteristic grasses of the Northwest. Western wheat grass (*Agropyron spicatum*, fig. 7), known to many of the ranchers as bluestem, is one of the best native grasses for hay, and efforts are being made to extend its cultivation. Meadow wheat grass, a closely allied species, is also a promising native variety. Bunch wheat grass (*Agropyron divergens*) may be classed as first among the dry-land species. It grows naturally in exceedingly dry soils and where the annual rainfall is very light. This wheat grass and the two feather grasses (*Stipa viridula* and *Stipa comata*), common to the same region, are the most promising species for regrassing the overstocked ranges.

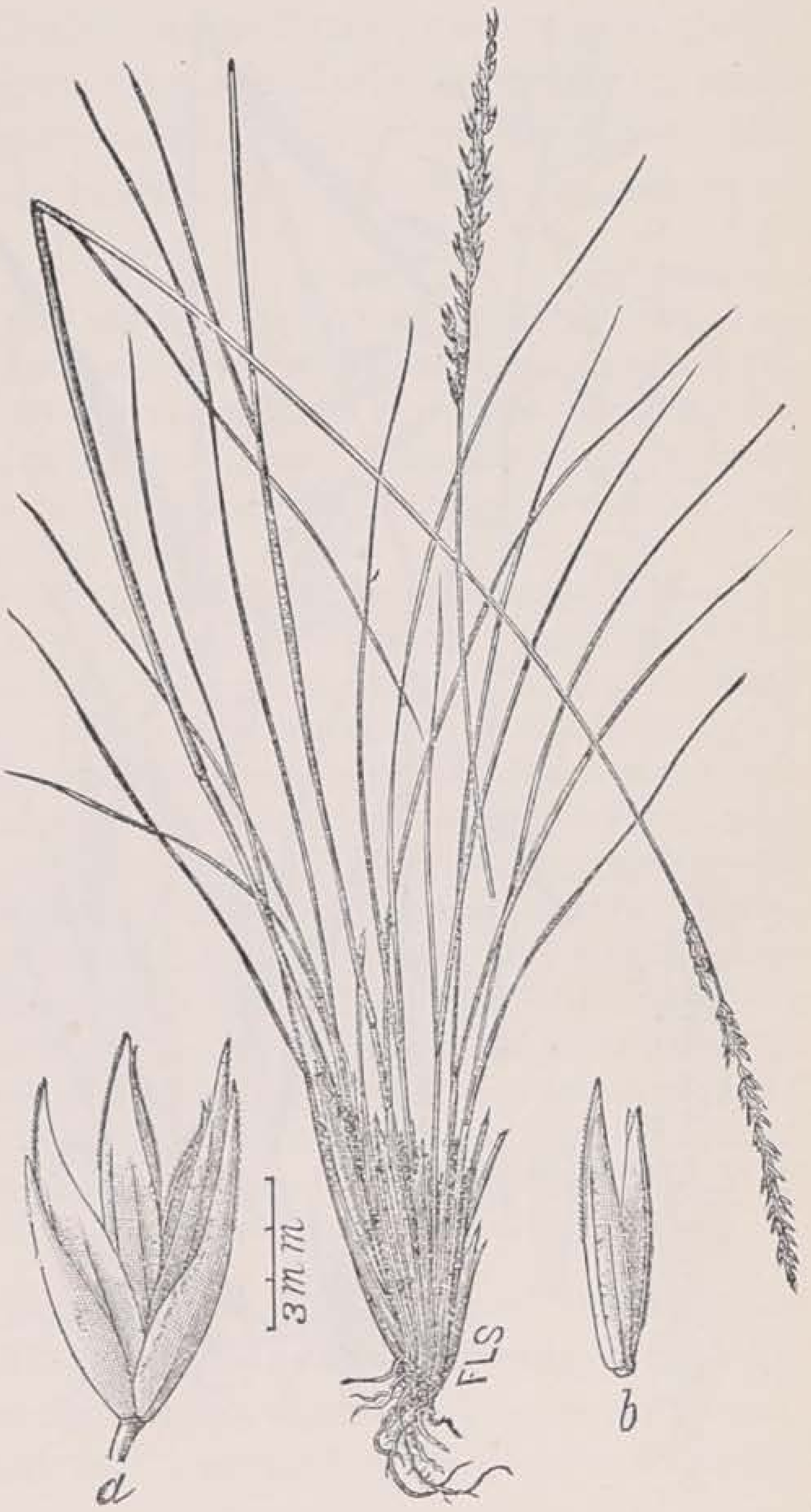

FIG. 8.—King's fescue (*Festuca kingii*): *a*, spikelet; *b*, floret.

Blue grama and side-oats grama.—Blue grama (*Bouteloua oligostachya*), known also in some sections of Montana as buffalo grass, is one of the pasture grasses among our native species. It is readily propagated by seed and thrives in almost any soil. It has been grown at all of the stations and by many volunteer experimenters. It apparently does as well in Washington, D. C., in the heavy clay soils as in the light and dry soils of eastern Washington. Side-oats grama (*Bouteloua curtipendula*) has a wider natural range, and although making a turf inferior to that of blue grama, it is nevertheless an excellent pasture grass, and under favorable circumstances yields an abundant hay crop.

Fescue grasses.—The mountain districts afford many native species of fescues. Creeping fescue and sheep's fescue exist in many varieties, some of them possessing great points of excellence. Aside from these two species there are others of equal value. King's fescue (*Festuca kingii*, fig. 8) is one of these. It is a native of Colorado, and it has been successfully propagated by seed, which it yields abundantly. Buffalo bunch-grass covers extensive meadows in Montana, affording excellent grazing, and is occasionally cut for hay, being very productive. It grows to the height of 3 or 4 feet, and its introduction into agriculture will be a test of its merits under cultivation.

FIG 9.—Smooth brome grass (*Bromus inermis*): *a*, spikelet; *b*, flowering glume seen from the back; *c*, floret seen from the anterior side, showing palea.

Brome grasses.—Native brome grasses are well worth more attention than has been given them. They seed abundantly, the seed is easily harvested, and germinates readily. The Division of Agrostology has tried several of the Western species, and from the limited experiments made, it is evident that there are important grasses in this group. *Bromus pumpellianus*, a native of Montana, Colorado, and Wyoming, is hardly to be distinguished from the European smooth brome (*Bromus inermis*, fig. 9), the introduction of which has done so much to improve the stock interests of the country.

The above list might be greatly extended, for there are many species as deserving of notice as those here mentioned. Bulletin No. 14 of the Division of Agrostology treats of the economic grasses and gives an extended list of the same.

Forage plants.—There are many forage plants which do not belong to the order Gramineæ. The greater proportion of these, and those which are generally regarded as the most valuable, belong to the Leguminosæ, or family of legume-bearing plants, which includes the clovers, vetches, beans, peas, lupines, etc. There are seventy varieties of native clovers, ninety lupines, forty vetches, and half as many wild beans, from among which doubtless selections can be made of varieties possessing special qualities superior to any of those now cultivated.

The leguminous forage crops, which now play such an important part in agriculture, were made the subject of a paper from the Division in the Yearbook for 1897. The cultivation of these plants is increasing every year, and their great value as soil renovators and cheap producers of fodder, rich in nitrogenous compounds, is becoming more and more widely known and appreciated. Referring briefly to the history of the cultivation of these plants, the writer of the paper in question states:

> The oldest cultivated forage plants and the best for enriching the soil are those of the clover family. Not one of the now well-known hay or pasture grasses has been cultivated more than three hundred years, while a number of leguminous crops have been grown for forage from prehistoric times. The chick-pea, or gram, dates back full thirty centuries. It is to-day one of the leading grain crops and soil renovators of Spain, India, and central Asia.
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> Alfalfa, which is recognized as the best forage plant in the semiarid Western States, or wherever dependence must be placed upon irrigation, was cultivated by the Romans at least two hundred years before the commencement of the Christian era. The soy beans have been grown in China and Japan and lentils in Hungary from prehistoric times. The field pea, originally from northern Italy, was introduced into cultivation eight or ten centuries ago. Sainfoin was grown in France and red clover in Media during the early years of the fifteenth century, and white, or Dutch, clover in Holland at the beginning of the eighteenth century. Sulla, which is largely grown in southern Italy and northern Africa, and which seems to be admirably adapted to well-drained soils in Florida and the Gulf States, was first introduced into cultivation in 1766. The cowpea has been known in this country nearly as long as sulla. Alsike, or Swedish clover, was taken up as a forage about thirty years later, while during this century and within recent years a score or more of valuable legumes have been brought to the attention of the farmer, and hardly a year passes that new ones are not added to the list.

One of the most recently introduced and promising of the leguminous plants is the velvet bean, a native of India. Its range of profitable cultivation is limited to the Southern States. The velvet bean is fully described and illustrated in Circular No. 14 of the Division of Agrostology.

The saltbushes of this country are very numerous in variety and often cover extensive areas in the far Western States and Territories. Their value to the stockmen of the West is clearly set forth in Bulletin No. 13 on the "Red Desert of Wyoming and its forage resources," and a number of both the native and introduced species are described in Farmers' Bulletin No. 108, which is devoted exclusively to them. It is only within the last few years that the forage value of these plants has been recognized in this country, and their importance in increasing our forage supply is fully treated of in a paper on "Forage clovers, vetches, beans, peas, lupines, etc. There are seventy varieties of native clovers, ninety lupines, forty vetches, and half as many wild beans, from among which doubtless selections can be made of varieties possessing special qualities superior to any of those now cultivated.

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> Alfalfa, which is recognized as the best forage plant in the semiarid Western States, or wherever dependence must be placed upon irrigation, was cultivated by the Romans at least two hundred years before the commencement of the Christian era. The soy beans have been grown in China and Japan and lentils in Hungary from prehistoric times. The field pea, originally from northern Italy, was introduced into cultivation eight or ten centuries ago. Sainfoin was grown in France and red clover in Media during the early years of the fifteenth century, and white, or Dutch, clover in Holland at the beginning of the eighteenth century. Sulla, which is largely grown in southern Italy and northern Africa, and which seems to be admirably adapted to well-drained soils in Florida and the Gulf States, was first introduced into cultivation in 1766. The cowpea has been known in this country nearly as long as sulla. Alsike, or Swedish clover, was taken up as a forage about thirty years later, while during this century and within recent years a score or more of valuable legumes have been brought to the attention of the farmer, and hardly a year passes that new ones are not added to the list.

One of the most recently introduced and promising of the leguminous plants is the velvet bean, a native of India. Its range of profitable cultivation is limited to the Southern States. The velvet bean is fully described and illustrated in Circular No. 14 of the Division of Agrostology.

The saltbushes of this country are very numerous in variety and often cover extensive areas in the far Western States and Territories. Their value to the stockmen of the West is clearly set forth in Bulletin No. 13 on the "Red Desert of Wyoming and its forage resources," and a number of both the native and introduced species are described in Farmers' Bulletin No. 108, which is devoted exclusively to them. It is only within the last few years that the forage value of these plants has been recognized in this country, and their importance in increasing our forage supply is fully treated of in a paper on "Forage plants for alkali soils," in the Yearbook for 1898, as already noted. It is for reclaiming or rendering valuable for grazing purposes soils highly impregnated with alkali that these plants are especially useful. The following is from the paper just referred to:

The saltbushes and salt sages, both introduced and native, have proved to be of value in all alkali-impregnated soils. A more extended cultivation of saltbushes is recommended throughout the West, and while trials are being made with the Australian species, the native forms, many of them being fully as leafy and having as succulent herbage, should not be overlooked. It is probable that quite a number of the thirty or more salt sages and saltbushes that grow wild on the high plains, mesas, and deserts of the West would, if only given an equally favorable opportunity, prove to be as well adapted to cultivation as any of the foreign species. As the West is developed the amount of grazing land is each year decreasing and the extensive areas of alkali-impregnated soils are becoming more valuable. The increase of these soils in value in the estimation of the Western cattle growers will come through the use of saltbushes and other alkali-tolerant forage plants.

Through the Division of Agrostology the Department has distributed the seeds of a number of the native saltbushes and quantities of several of the Australian species, the one receiving the most attention being the Australian saltbush (*Atriplex semibaccata*). Seed of this species was introduced into this country nearly twenty years ago by the California experiment station at Berkeley, but it has been only within the last year or two that it has received any widespread attention. During the present season large quantities of the seed have been distributed by the Secretary of Agriculture in regions where this saltbush is likely to prove most useful in the way of increasing the forage resources of our country.

VOLUNTEER EXPERIMENTERS.—Much of the work done by the Division of Agrostology in testing the adaptability of varieties to the prevailing conditions in different sections of the United States has been carried on in cooperation with farmers and stockmen as well as with a number of State experiment stations. These tests or experiments have been made chiefly by sending the experimenters seeds of the grasses or forage plants which have been collected or obtained by purchase, and requesting that reports be made as to the success or failure of the attempts made to grow them. Nearly ten thousand packages of seeds, including two hundred and fifty-five varieties, have been sent out in this way to those expressing their willingness or desire to cooperate with the Division. The reports received on account of this method of seed distribution during the past three years have been prepared for publication as Bulletin No. 22, which will serve to illustrate very well what can be accomplished in acquiring a practical knowledge of grasses and forage plants through volunteer experimenters. These experiments have proved of great value, not only as being the means of finding out the suitability of varieties for cultivation in different sections of the country, but also of bringing the work of the Division in closer touch with the people whom it is designed to serve. The results of these tests have shown that many of the valuable native grasses adapt themselves readily to cultivation, and have also demonstrated the value of some of the newly introduced varieties, as well as the possibility of a wider cultivation of many of those already commonly grown in the United States. Thus, it has been discovered that slender wheat grass and a number of the native bromes and blue grasses can be utilized in the formation of artificial meadows and pastures; that other of the wheat grasses, the grama grasses, blue grasses, and native fescues may be utilized in reclaiming the worn-out ranges in the drier sections of the country; that smooth, or Hungarian, brome grass, recently introduced from the Old World, is a most valuable hay and pasture variety for the drier sections of the West and Northwest; that Australian saltbush, as well as a number of native saltbushes, is well adapted to cultivation on lands strongly impregnated with alkali, such as are found in many parts of the Southwest; and the experiments now in progress seem likely to demonstrate the value of other varieties in certain sections, such as oasis alfalfa for the hot, dry Southwest, and Turkestan alfalfa for the dry sections of the Northwest where the climate is colder.

SOME RESULTS OF WORK OF DIVISION OF AGROSTOLOGY.—The Secretary of Agriculture, in summing up the work of the Division of Agrostology in 1898, said:

Through the efforts of this Division we are learning the needs of the several sections of the country and the forage problems they have to meet. We are acquiring a better knowledge of the distribution and value of our native grasses and forage plants, as well as the peculiar conditions of soil and climate best suited to their growth.

The discovery of new economic grasses or new and valuable forage plants, the adaptability of the native species to cultivation, the introduction of forage plants into new or untried regions, the application of species to new or special uses, and the general diffusion of knowledge through publications and correspondence respecting these plants are among the important results of the work of the Division.

EXTENSION OF INVESTIGATIONS.—Through the Division of Agrostology the Secretary of Agriculture is working not only to produce more and better hay on every acre of meadow land, but also to preserve or improve the great cattle ranges of the West and the pasture lands of the whole country. In the Report of 1899, the Secretary says:

The investigations under way in the Gulf-coast region and on the Pacific slope ought to be extended in their scope; the work on range improvement should be continued along the present practical lines; the investigations looking toward the preservation and improvement of our most valuable native grasses and forage plants should be continued; the study of soil and sand-binding grasses ought to be extended to include experiments as to the adaptability of our native sorts to practical use for fixing the shifting sands of our coasts and for holding embankments in place, as well as to the introduction of desirable foreign sorts; investigations relative to the introduction, cultivation, and management of improved pasture and forage crops on the worn-out farms of the East should be undertaken; the question of forage crops suitable to alkali soils is one of much importance to certain sections of the country, and should receive full and careful investigation.

APPLIED AGROSTOLOGY IN THE STATE AGRICULTURAL EXPERIMENT STATIONS.

Nearly all the State experiment stations, ever since their organization in 1887, have given more or less attention to the subject of grasses and forage plants, and a few of them have made this a leading feature of their work. Among the first to undertake work along these lines was the California experiment station at Berkeley, and this station, under the direction of Prof. E. W. Hilgard, has done very much toward the introduction of valuable forage plants into that State by the distribution of seeds of many varieties. Other stations which have given special attention to grass and forage-plant investigations are those in Nebraska, South Dakota, Tennessee, Mississippi, Alabama, Ohio, Connecticut (Storrs), Kansas, Michigan, New York, Minnesota, and Massachusetts.

Over two hundred bulletins and reports have been issued by the several stations on the subject of grasses and forage plants—a fact which in itself demonstrates the great interest taken in these investigations and the manifest importance attached to the subject. Some of the stations have published descriptive and illustrated grass floras of the States in which they are located, which have done much toward disseminating a knowledge of grasses and inciting greater interest in the improvement of forage resources. One of the most complete and elaborate of these floras is that published by the Tennessee station, in which all the grasses known to occur within the State are illustrated.

The effect of the grass and forage-plant investigations which have been carried on by the Department of Agriculture during recent years, together with similar investigations at the different State experiment stations, is seen at the present time in the changed methods of farming that are being practiced in many sections of the country. This is well illustrated in the South, where but a few years ago it was thought by many that the better cultivated grasses and forage plants could not be successfully grown. It is also illustrated in the improved methods of handling pastures and ranges that are coming into practice in many parts of the West, and in the greater diversity of the grass and forage crops that are grown in almost all sections of the country where dairying is a leading industry.

SCIENTIFIC, OR SYSTEMATIC, AGROSTOLOGY.

At the beginning of the century the number of known North American grasses barely exceeded one hundred species. These had been published chiefly in the works of Linnæus, Lamarck, and Walter. In 1803 Michaux published his "Flora Boreali Americana," in which he describes as new sixty-eight species. Michaux's work was soon followed by those of Persoon, Pursh, Nuttall, Muhlenberg, Elliott, and Beauvois, in which many new North American species were published. Beauvois, in his "Agrostographiæ," undertook to establish a natural arrangement of the whole Gramineæ, with descriptions of the genera then known, together with many new ones, some of which were North American, and the majority of which have since been adopted. Between 1820 and 1850 appeared the great works of Kunth, Trinius, and Nees von Esenbeck, in whose writings, especially those of Trinius, who confined himself exclusively to grasses, many North American species were published for the first time. It was during this period that the great American botanists, Drs. John Torrey and Asa Gray, did much to advance our knowledge of North American plants, and many new species of Gramineæ appear in their various works. These authors, especially Dr. Gray, whose publications continued until a comparatively recent date, made further additions to agrostological science, and their works are essential to the student of grasses to-day.

Steudel in 1855 published the first volume of his "Synopsis Plantarum Glumacearum," which contains a general enumeration of the grasses of all countries, and is the last work in which such an enumeration has been attempted. All the older North American species are included, and Steudel describes many new ones, some few of which are still retained.

The knowledge of Southern grasses was greatly advanced by the publication of Chapman's "Flora of the Southern United States" in 1862. Grisebach, in his "Flora of the British West Indies," published in 1864, described a number of species which come within our southern limits, and in Ledebour's "Flora Rossica," which appeared in 1853, many species common in Alaska are published for the first time. In England, General Munro was for many years the leading authority on grasses, and in this country Dr. George Thurber was the court of last resort in all pertaining to American grasses. The chief contribution to agrostology made by the former was his monograph on the tribe Arundinariæ, and the latter is best known to the student of grasses to-day by his contribution to Brewer and Watson's Botany of California, published in 1880, in which all the species of that State then known were fully described.

A marked impetus was given to the study of grasses by English-speaking students by the publication of Bentham's "Notes on grasses," in 1881, in the Journal of the Linnæan Society. In this work the several tribes and genera are discussed. The classification presented is essentially based upon the opinions of General Munro and finally adopted in the third volume of Bentham and Hooker's "Genera Plantarum," published in 1883. A work of much interest to the student of the grasses of the Southwest is Fournier's "Gramineæ" in his "Enumeration of Mexican plants," published early in the last decade. It is the only work especially devoted to the grasses of Mexico, and includes many species occurring in the States and Territories bordering that country. After the death of General Munro, in 1880, Prof. E. Hackel, of St. Poelten, Austria, was at once recognized as the highest authority on grasses, and his contribution to the great German work on the "Natural families of plants," by Engler and Prantl, is ample evidence of his right to the position. An American translation of this work, under the title of "The true grasses," published in 1890, has done much to promote the study of systematic agrostology in this country. It presents in a clear and concise manner the general features of the grass family, enumerating the best-known economic species, discussing their structure and morphology, and their arrangement into tribes and genera, thus placing in the hands of the American student a manual by which he is enabled to classify any grass which may come into his hand, and materially assisting the systematic study of grasses, which now forms such an important feature in the curriculum of nearly all our agricultural colleges.

In 1889 Hackel published an extensive monograph of the Andropogoneæ, in which all the North American species of that tribe then known are fully described, a few of which are presented as new to science. The system of classification of the tribes and genera of the Gramineæ presented by Hackel in his "True grasses," and now generally adopted in this country, was much modified by Baillon in his "Monographie des Graminées," published in Paris in 1893. This is the latest general treatment of the grass family as a whole that is of special interest to the student of American grasses. In this work not only is there a decided modification in the limitation and arrangement of the tribes and genera from that proposed by Bentham and by Hackel, but an attempt is made to adopt the more advanced system of nomenclature.

Four years ago, in 1896, Prof W. J. Beal, of the Michigan Agricultural College, published the second volume of his work on the "Grasses of North America," wherein are brought together for the first time descriptions of all the North American species known to the author. He enumerates over one thousand three hundred species, including many from Mexico and Central America, with full descriptions. No other single publication covers the same extended field.

SYSTEMATIC AGROSTOLOGY IN THE DEPARTMENT OF AGRICULTURE.

While the Department of Agriculture has always been more or less active in promoting the interests of applied agrostology, it has in later years been hardly less energetic in advancing scientific knowledge of grasses and developing a wider interest on systematic lines. Immediately following the publication of the third volume of Bentham and Hooker's "Genera Plantarum," already referred to, Dr. George Vasey, then Botanist of the Department, published as a special report a list of the grasses of the United States, together with a synopsis of the tribes and genera, which were chiefly translated from Bentham and Hooker's work. Two years later, in 1885, a revised and somewhat enlarged edition of this list was published under the title of "A descriptive catalogue of the grasses of the United States." This work included many economic notes, and was prepared with the view of assisting both the scientific student and the farmer. Between the years 1891 and 1893 the Department published two volumes prepared by Dr. Vasey, containing descriptions and full lithographic plates of two hundred species of grasses belonging to the region of the Southwest and the Pacific slope. The illustrations in this work are for the most part excellent and the descriptions are very full. The plan adopted is not unlike that of Trinius's "Icones," and it is a matter of regret that the work could not have been continued until all of the American species were illustrated in the same manner. In 1892 Dr. Vasey published as Part I to Vol. III of the "Contributions from the U. S. National Herbarium" what he designated as Part I of a "Monograph of the grasses of the United States." Following the classification of Prof. Edward Hackel this part contains descriptions of all the North American species of grasses known to the writer through the subtribe Phleoideæ in the seventh tribe Agrostideæ. At the time of his death (March 4, 1893), Dr. Vasey had prepared the manuscript of a considerable portion of the second part of this monograph, but the work in the form in which it then appeared has not been continued. During the years between 1881 and 1893 Dr. Vasey published many new species of North American grasses, not only in the bulletins issued by the Department, but in the leading botanical journals and in the proceedings of scientific societies. The total number of species published by him between 1885 and the time of his death was one hundred, and nearly as many new varieties.

Since the establishment of the Division of Agrostology in 1895, systematic work on grasses has been continued by the Agrostologist and his assistants. Papers which may be classed as belonging to systematic agrostology have been published in Bulletins Nos. 4, 7, 8, 11, 17, 18, 19, and in Circulars Nos. 9, 10, 15, 16, and 19 of the Division. Circular No. 15, published July 14, relates to "Recent additions to systematic agrostology," while the other circulars referred to contain chiefly descriptions of new species. Under the general title "Studies on American grasses," to which Bulletins Nos. 4, 8, 11, and 18 belong, there have been published revisions of certain North American genera and enumerations of species collected in the little-known regions, and a large number of species presumably new have been described. In Bulletin No. 19 there was published a very carefully prepared paper on the structure of the seeds of grasses, the investigations being made largely with the view of establishing a basis of classification upon the Caryopsis. Six hundred and twenty-seven North American grasses are figured and described in Bulletins Nos. 7 and 17. The illustrations in these two bulletins are all drawn from original material and form a part of a series which, when complete, will illustrate all of our North American grasses. The Agrostologist has also published in botanical journals and in proceedings of scientific societies many papers bearing on the subject of systematic agrostology, notably among these may be mentioned "Notes on the grasses in the Bernhardi Herbarium, collected by Thaddeus Haenke and described by J. S. Presl," published in the Tenth Annual Report of the Missouri Botanical Gardens. This paper is illustrated by fifty-four plates, drawn from the types of species described by Presl in "Reliquiæ Haenkeanæ." In these various papers and in the publications of the Division, the Agrostologist has during the last five years published one hundred and twenty-five species and thirty-three varieties.

A good herbarium or collection of grasses forms an essential part—is, in fact, the basis of all work in systematic agrostology. The Division of Agrostology, since its organization, has been steadily at work building up an herbarium of grasses, until now the collection numbers nearly thirty-five thousand mounted sheets of specimens, more than twenty-five thousand of which have been added during the past five years. This collection, which forms no inconsiderable part of the great National Herbarium located in Washington City, is especially valuable, not only on account of its richness in North American species, but also on account of its containing a great many types of the species published in recent years.

SYSTEMATIC AGROSTOLOGY IN THE STATE AGRICULTURAL EXPERIMENT STATIONS.

It is believed that the work of the Department of Agriculture in the way of scientific investigation of grasses has done much to develop similar lines of work in the agricultural experiment stations. The work at these stations, in order to meet the demands of the people, must of necessity be more along the lines of applied agrostology. Several of the stations have, however, published descriptions of the grasses of the States in which they are located. In 1894 the Tennessee Agricultural Experiment Station published a bulletin in which all the species known to occur within the State were fully described and illustrated. This work contained keys of analysis to the tribes and genera, and in the larger genera to the species also. Less fully illustrated descriptive bulletins have been published by several other stations, but comparatively little original work has been done by any of them along systematic lines. The Division has lent material aid to this work, not only through its several publications, but by the distribution of many thousands of named specimens of grasses to these agricultural experiment stations. As illustrating the attention now paid to systematic agrostology and the rapid progress being made in this branch of the subject, it may be stated that during the last five years three hundred and seventy-four new species of North American grasses and one hundred and sixty-six new varieties have been published.

PROGRESS OF ROAD BUILDING IN THE UNITED STATES.

By Maurice O. Eldridge,

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INTRODUCTION.

The history of road building in the United States parallels in but few particulars the road history of the other great civilized nations of the world, and in many respects our highways bear but slight resemblance to those of the older countries. There is little doubt that had the first settlers arrived in this country when the Roman Empire was at the zenith of its glory our Republic would now be bound together with a perfect system of magnificently constructed highways, but when America was settled by the English, in the early part of the seventeenth century, the mother country was still using those systems in road building which it had inherited from the dark ages.

The Britons neglected the roads which had been made by the Romans, and, failing to build new ones, their country for centuries was provided with only bridle paths, or at most with narrow highways for small carts. These highways were, except in dry weather, practically impassable, and in the sparsely settled districts much of the travel had to be carried on by means of pack animals. The idea of a central control of road systems, which is the only means by which any extended work in this direction has ever been accomplished, had died out in the middle ages and had not at this time been revived. For these reasons the traditions relative to the construction and management of roads which followed the first settlers to this country were practically valueless.

ROAD METHODS OF THE FIRST SETTLERS.

The first settlements in the United States were naturally located along the seashore and upon the banks of navigable streams. Narrow and mysterious Indian trails led from the settlements along the coast to the interior, and aside from an occasional rude path beside some stream or along the coast, these were the only lines of communication up to the end of the seventeenth century. Indeed, for a century after the settlement at Plymouth Rock there were few roads in this country over which goods or passengers could be transported in wagons or carriages.

The little traffic and intercourse that were carried on between the settlements was maintained principally by boats or by horsemen or pack trains over the obscure Indian trails. A systematic attempt at road building was then, of course, impossible, owing to the crude state of society and the sparse population. Soon there was an eagerness to penetrate the vast wilderness of the interior and communicate with settlers in other regions by shorter routes than those afforded by the winding streams. Acting upon this impulse, the pioneer blazed his way through the forests and brambles. He made temporary bridges over the streams by felling large trees across them, and threw brush and poles over the boggy places in his bridle paths. With the steady increase in wealth and population, this "pack-train era" in road building was gradually superseded by original trackways or widened trails and then by wagon roads, but without any attempt at improvement. Another century elapsed before anything like improved highways was established outside the eastern coast districts, and it was not until the beginning of the present century that there were any well-built roads in the rural communities.

ONE OF THE EARLIEST ROADS IN THE UNITED STATES.

The first great American road which the historian tells anything about was laid out in 1711, and ran from New York to Philadelphia. Its antiquity, and the fact that it connected these two cities, gave to it the name "The Old York Road." The opening of roads was an important affair in those days; money was more scarce than it is now, and doubtless it was more of an undertaking to construct roads than it is to build the railways of to-day. By studying the history of the Old York Road we at once realize the potency of the adage that "the history of roads is the history of civilization." The Indian trail, the blazed trees, and the footpath, followed by the bridle road for pack trains, and then thé rough roads for carts and wagons, which were subsequently graded and paved, making a more easy means of transportation, are all stepping stones to higher degrees of civilization.[1]

FORCED-LABOR SYSTEM AND ROADS OF THE EARLY COLONISTS.

In the early colonial days the roads were at first built and maintained principally by the use of volunteer aid or free labor. Each town or settlement had what was called a "village green," and in this open place the citizens assembled to discuss matters of public import. At these meetings the care of the poor, the infirm, the deaf mutes, etc., was discussed; the opening of new and the maintenance of the old roads were also among the most interesting subjects of discussion. The citizens would here offer their services free of charge to the community or town for building or maintaining the roads running through or by their lands. These offers to maintain the roads free of charge soon became so limited, however, that the towns were forced to pass

[1]The York Road Old and the New Fox Chase and Bustileton, by S. F. Hotchkin.

ordinances compelling all able-bodied men to "work the road" a specified number of days, or in lieu of such labor to pay a money tax to the pathmaster or road overseer. It is easy to trace progress in all those matters which were discussed on the "village green" save one, and that is the "forced-labor" system of working roads, which exists in most of the States to this day.

The following extract, relating to the early methods of locating and building roads, is copied from a letter dated November 30, 1785, written by George Washington to Patrick Henry, then governor of Virginia:

Do you not think, my dear sir, that the credit, the saving, and convenience of this country all require that our great roads leading from one place to another should be straightened, shortened, and established by law, and the power in the county courts to alter them be withdrawn? To me these things seem indispensably necessary, and it is my opinion they will take place in time. The longer, therefore, they are delayed, the more people will be injured by the alterations when they happen. It is equally clear to me that, putting the lowest valuation upon the labor of the people who work upon the roads under the existing law and the customs of the present day, the repairs of them by way of contract, to be paid by an assessment on a certain district, until the period shall arrive when turnpikes may with propriety be established, would be infinitely less burthensome to the community than the present mode. In this case the contractor would meet no favor; every man in the district would give information of neglects; whereas negligence under the present system is winked at by the only people who know the particulars or can inform against the overseers, for strangers had rather encounter the inconvenience of bad roads than the trouble of an information, and go away prejudiced against the country for the polity of it.[1]

This system of "working out" the tax was as unsatisfactory in the days of Washington as it is now. Much delay and inconvenience was caused by the deplorable condition of the main roads. The ruts were deep, the hills steep and full of gullies, and when stagecoaches were first used travelers were often compelled to get out and assist the driver in pulling the vehicle out of the mud. Even the roads running out of the large cities and towns were no exception to the general rule; they were often in such wretched condition that passage was rendered difficult and sometimes dangerous. It was no uncommon sight to see the horses floundering in mud up to their haunches.

York road, running out of Philadelphia, was a quagmire of black mud for nine months of the year, and on this road long lines of wagons were every day to be met with drawn up near Logan's Hill, where the wagoners unhitched their teams to assist each other in pulling through the deep sloughs. Sticks or rails were often stuck up to warn travelers out of the quicksand or mud holes, and the fences were sometimes pulled down in order to permit passage through the adjacent fields.[2]

In 1796 the worst road in the country was said to be the one from Elkton, Md., to the Susquehanna Ferry. It was so uneven and full

[1] Writings of Washington, Vol. XII, edited by J. Sparks.

[2] Watson's Annals of Philadelphia and Pennsylvania in the Olden Times.

of holes that stagecoach passengers were often requested by the driver to lean out the side of the coach to prevent being overturned. "Now, gentlemen," he would say, "to the right;" "Now, gentlemen, to the left."[1]

INAUGURATION OF TURNPIKE ROADS BY CHARTERED COMPANIES.

The making of turnpike roads by chartered companies was inaugurated in the last quarter of the eighteenth century with the advance of population to the West. State and national charters were given to many turnpike companies, which at first yielded large profits to capitalists. The establishment of turnpikes and the maintenance of them by toll, however, effected but little improvement in the general system, and the tax imposed upon those who were compelled to use many of these roads was not paid without protest.

THE WILDERNESS TURNPIKE.

The Wilderness Turnpike was the name of one of the earliest of these roads. From the Shenandoah Valley, in Virginia, it followed for some distance the Holston River; thence it crossed the Allegheny Mountains at Cumberland Gap to central Kentucky. This route was opened at first for pack trains, but afterwards was so improved that it became the main road for wagon trains from Virginia to the valley of the Ohio. A large commerce was carried on between Virginia and the West over this highway, and it proved very advantageous to Kentucky and adjacent States in their early settlement and development. During the first decade of this century the Wilderness Turnpike was the best highway south of the Potomac River; but soon the traffic began to decrease and the revenues became so limited that it was neglected. For years, however, the tollgates were maintained and travelers were required to pay a toll of $2 on passing the gates, which were 70 miles apart, although tools frequently had to be carried in the vehicle with which to repair the portions of the road that were impassable.[2]

THE PHILADELPHIA-LANCASTER TURNPIKE.

The desire to speculate in those days was as great as it is now, and such were the profits of some of these roads that they were often the subject of speculation. A notable example of this is shown by the organization of a company in 1792 to build a turnpike from Philadelphia to Lancaster, Pa., a distance of 60 miles. The charter was secured, and in ten days 2,275 subscribers made application for stock. As this was more than the law allowed, the names were placed in a lottery wheel and 600 were drawn; with these subscriptions the work began. The road builders of that day knew little or nothing regarding

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[1] History of the People of the United States.

[2] N. S. Shaler, American Highways, pp. 19 and 93.

the construction of highways, and the mistakes made on this occasion taught them some valuable lessons. The land was condemned, the trees felled, and the roadbed prepared. The largest stones that could be found were dumped upon it for a foundation, and upon this colossal base earth and gravel were spread; then the work was declared complete; but when the washing rains came deep holes appeared on every hand, sharp stones protruded from the surface, and the horses received scratched and broken limbs as they sank between the bowlders up to their knees. The gigantic error of the road builder was then made plain. Indignation meetings were held, at which the turnpike company was condemned and the legislature blamed for giving the charter. Had it not been for an Englishman who offered to rebuild the turnpike on the macadam plan, as he had seen roads built in the old country, improved road construction would have received a severe blow. The Englishman's proposition was accepted by the company, and he was successful in completing the Lancaster and Philadelphia turnpike road, which was then declared to be "the best piece of highway in the United States—a masterpiece of its kind."[1]

ERA OF SPECULATION AND RESTORATION OF FORCED-LABOR SYSTEM.

The success of the Lancaster pike encouraged road building everywhere, and before the first decade of the new century had elapsed many of the well-settled States were voting money, setting apart revenues derived from the sale of public lands, and establishing lotteries to build turnpikes between prosperous towns in the East and to the frontier. The prospect of increasing their land values by the building of good roads and the fascination of receiving large dividends from investments induced many people to risk their all upon these schemes. Speculation was rife in the land, turnpike building rapidly became the rage, and in a few years a sum almost as large as the public debt at the close of the Revolution was invested by the people in turnpike ventures. By 1811 over 317 pikes had been chartered in New York and in the New England States, their total length being 4,500 miles and their combined capital over $7,500,000. Hundreds of miles of public turnpikes[2] were constructed in New York and in some of the Western States with thick, wide boards or planks, and for a few years it was thought that this method would supersede all others. While the planks lasted the roads were good; but the boards decayed very rapidly, and for this reason the method, proving unsuccessful, was

[1] History of the People of the United States, Vol. II, p. 554.

[2] The term "turnpike" is of medieval origin, having been first used in England to designate a graded road, for the use of which travelers were expected to pay toll. A pike across the road indicated a tollgate, where the traveler was required to stop before proceeding on his journey. After he had paid the fees the pike was turned and he was allowed to go on his way. "Turnpike" has now come to mean any public highway constructed of stone or gravel. As a rule, however, the term is only applied to a toll road or one upon which formerly toll was collected.

gradually abandoned. Except for a few short stretches in the New England and the Southern States, the toll system also proved unsuccessful, and many of the companies lost money. Some surrendered their charters and others were bought out by the States or counties. The turnpike system was gradually superseded by the restoration of the "forced-labor" system, explained elsewhere, and until within the last few years this method was universally followed, each county taking care of its own highways. The States exercised no supervision whatever, and skilled road builders or road engineers were unheard of. The "forced-labor" system was borrowed by our ancestors from the dark ages, and is not unlike the "militia" system adopted in Kentucky and a few other Southern States.

NATIONAL HIGHWAYS.

Early in the present century, with the movement started in England by Telford and Macadam in favor of broken-stone roads, the importance of improved roads for military, postal, and commercial purposes began to be widely appreciated. Road reform assumed such proportions that it was advocated by many of the great patriots of the day; indeed, the movement waxed so strong in this country that it became one of the leading questions of national politics, and was supported by such statesmen as Thomas Jefferson, John C. Calhoun, and Henry Clay. Next to the tariff, it was one of the most important subjects under consideration in Congress.

Those who believed in a liberal construction of the Constitution were favorable to the building of roads by the General Government, while the strict constructionists denied the power of the Government to spend money for any such internal improvements. During President Jefferson's second term the bill admitting Ohio as a State, passed April 30, 1802, contained a provision setting apart 5 per cent of the net proceeds from the sale of public lands in that State to the building of public roads leading from the navigable waters emptying into the Atlantic to and through the State of Ohio—3 per cent for road making within the State and 2 per cent for highways outside the State. Such roads were to be laid out under the authority of Congress and with the consent of the States through which they would pass.

THE CUMBERLAND ROAD.

In 1806 the sale of public lands in Ohio had amounted to over $600,000, and after some discussion in both Houses of Congress a bill appropriating $30,000 was passed. The construction of the so-called Cumberland road was then begun. From Cumberland, Md., it was to extend through southwestern Pennsylvania and over the Allegheny Mountains to the Ohio at Wheeling, W. Va., and then on to St. Louis, Mo. It was constructed after the principles advocated by Telford and Macadam, and was so well built that it is yet a good road, although

FIG. 1.—THE BIG CROSSING ON THE OLD CUMBERLAND ROAD, SUMMERVILLE, PA.

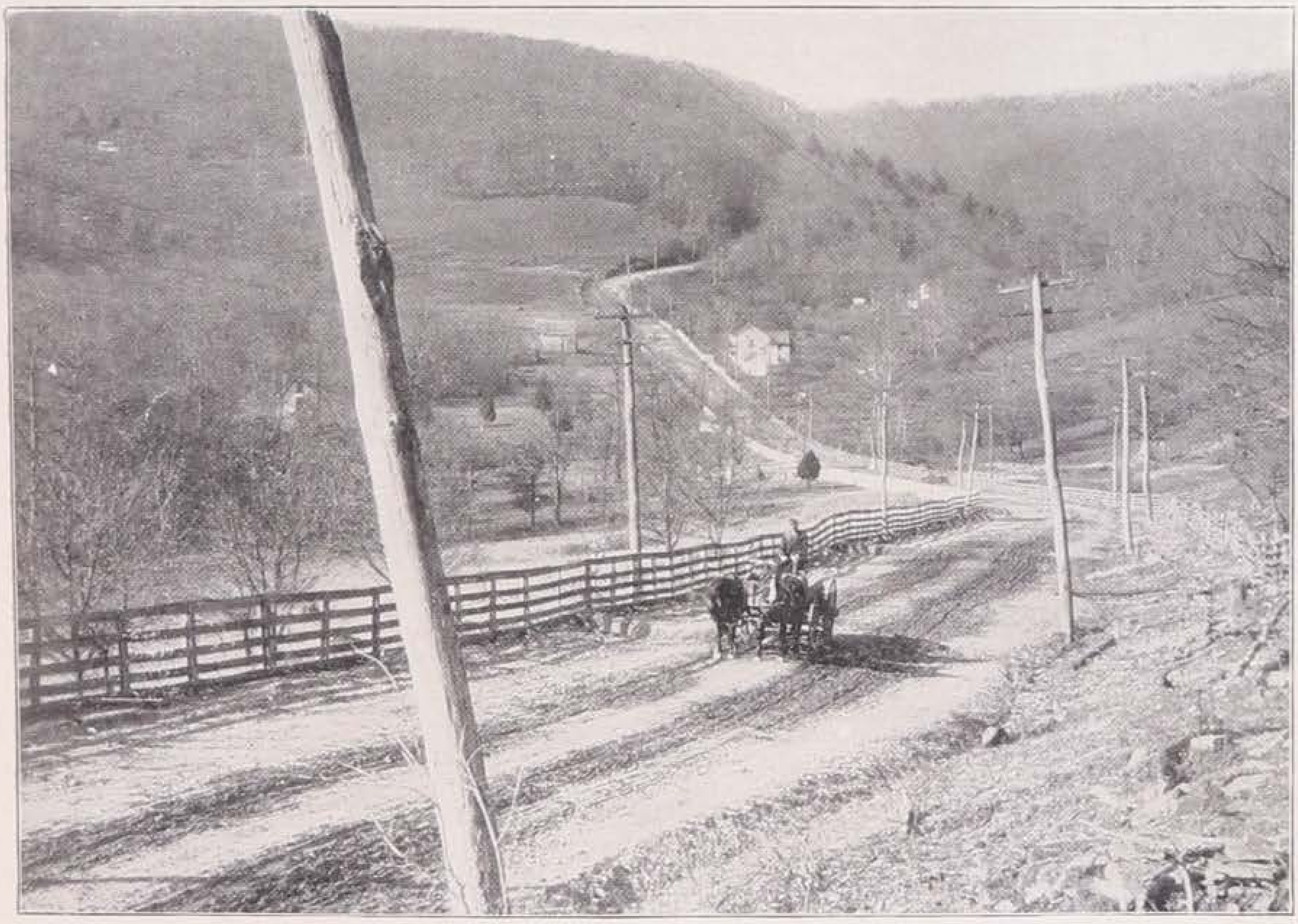


FIG. 2.—OLD CUMBERLAND ROAD APPROACHING CHESTNUT RIDGE MOUNTAINS, PENNSYLVANIA (LOOKING WEST).

it has since passed into the hands of the States in which it is located, and has not been systematically repaired for years. (Pl. XIII.) This road was well described by a writer in 1879, as follows:

It was excellently macadamized; the rivers and creeks were spanned by stone bridges; the distances were indexed by iron mileposts, and the tollhouses supplied with strong iron gates. Its projector and chief supporter was Henry Clay, whose services in its behalf are commemorated by a monument near Wheeling. There were sometimes twenty gaily painted four-horse coaches each way daily. The cattle and sheep were never out of sight. The canvas-covered wagons were drawn by six to twelve horses. Within a mile of the road the country was a wilderness, but on the highway the traffic was as dense as in the main street of a large town. Ten miles an hour is said to have been the usual speed for coaches, but between Hagerstown and Frederick they were claimed to have made 26 miles in two hours. These coaches finally ceased running in 1853. There were also through freight wagons from Baltimore to Wheeling which carried 10 tons. They were drawn by twelve horses, and their rear wheels were 10 feet high.

From Cumberland to Baltimore the road, or a large part of it, was built by certain banks of Maryland, which were rechartered in 1816 on condition that they should complete the work. So far from being a burden to them, it proved to be a most lucrative property for many years, yielding as much as 20 per cent, and it is only of late years that it has yielded no more than 2 or 3 per cent. The part built by the Federal Government was transferred to Maryland some time ago, and the tolls became a political perquisite; but within the past year it has been acquired by the counties of Allegany and Garrett, which have made it free.

From 1810 to 1816 six appropriations, amounting to $680,000, were made by Congress for continuing the work on this road.

PROPOSITION IN CONGRESS FOR A NATIONAL SYSTEM OF ROADS.

In 1817 John C. Calhoun, Henry Clay, and others favored the creation of a new fund for internal improvements. A bill was introduced in the House of Representatives by Mr. Calhoun to set aside for roads and canals the bonus and dividends received by the United States from its newly chartered national banks. In supporting this measure Mr. Calhoun, although a stanch believer in the doctrine of State rights, delivered a speech before the House in which he thus expressed himself:

Let it not be said that internal improvements may be wholly left to the enterprise of the States and of individuals. I know that much may justly be expected to be done by them; but in a country so new and so extensive as ours there is room enough for all, the General and State governments and individuals, to exert their resources. Many of the improvements contemplated are on too great a scale for the resources of States or of individuals, and many of such a nature that the rival jealousy of the State, if left alone, might prevent. They require the resources and general superintendence of the Government to effect and complete them.

But there are higher and more powerful considerations why Congress should take charge of this subject. If we were only to consider the pecuniary advantages of a good system of roads and canals, it might indeed admit of some doubt whether they ought not to be left wholly to individual exertions; but when we come to consider how intimately the strength and political prosperity of the Republic are connected with this subject, we find the most urgent reasons why we should apply our resources to them. Good roads and canals, judiciously laid out, are the proper remedy. Let us, then, bind the Republic together with a perfect system of roads and canals.

The first great object is to perfect the communication from Maine to Louisiana. This may be fairly considered as the principal artery of the whole system. The next is the connection of the lakes with the Hudson River. The next object of chief importance is to connect all the great commercial points on the Atlantic with the Western States, and, finally, to perfect the intercourse between the West and New Orleans. There are others, no doubt, of great importance which will receive the aid of the Government. The fund proposed to be set apart in this bill is about $650,000 a year, which is doubtless too small to effect such great objects of itself, but it will be a good beginning. Every portion of the community—the farmer, the mechanic, and the merchant—will feel its good effects; and, what is of greatest importance, the strength of the community will be greatly augmented and its political prosperity rendered more secure.

Henry Clay also spoke in favor of the proposed act, particularly in reference to its constitutional merits, but the House amended and passed it in such a manner as to enable the States to prosecute the work under the supervision of the National Government, and in this form it passed the Senate. On March 13, 1817, President Monroe vetoed this bill on the ground that he believed it to be unconstitutional, even though its provisions were agreed to by the States. An attempt was made to pass it over the President's head, but failed of the necessary two-thirds majority.

CONGRESSIONAL ACTION REGARDING ROAD BUILDING.

Upon the defeat of the bill for a national system of roads and for the funds for the same, Congress returned to its former method of providing for road building from funds derived from sale of public lands. In 1811, 5 per cent of the net proceeds of the sales of public lands in Louisiana were, as in the case of Ohio, given to that State for the building of roads and levees, in 1816 the same percentage of a similar fund was given to Indiana for roads and canals, and in 1817 a like sum was given to Mississippi for this purpose. In 1818, 2 per cent of a similar fund was given to Illinois for roads leading to that State; in 1819, 5 per cent to Alabama; in 1820, 5 per cent to Missouri, and in 1845, 5 per cent to Iowa. In the meantime the annual appropriations for the Cumberland road, of sums to be replaced from the funds thus set aside in the States through which it passed, were continued. For the fiscal year 1819 over half a million was donated, and on May 25, 1838, the last appropriation, amounting to $150,000, was made, the sum total being about $7,000,000.

While the Cumberland road was being built twelve other great national highways were laid out in the States and Territories, making what was then regarded a complete system of roads, and more or less work was done in opening and constructing them. Congress provided in 1806 for a road from the frontier of Georgia, leading toward New Orleans, La., and one from Nashville, Tenn., to Natchez, Miss.

From 1806 to 1838 a total of \$1,600,000 was appropriated by Congress for roads in various places, and of this sum \$200,000 was used in Florida; \$286,000 was expended for a road from Chicago, Ill., to Detroit, Mich., and other points; \$206,000 was also used toward the construction of a road from Memphis, Tenn., to the St. Francis River, in Arkansas. In addition to the appropriations above mentioned, grants of land have been made from time to time by the States to aid in the work, and the labor of United States troops has been occasionally employed.

In 1822 the regular appropriation for the Cumberland road was vetoed by President Monroe, and in 1830 the Maysville and Lexington turnpike bill, authorizing a Government subscription to the stock of a turnpike company in Kentucky, was passed by Congress, but was vetoed by President Jackson.

The monetary crisis of 1837 put a damper on all projects requiring large Government expenditures, and from that time to 1854 only a few small appropriations were made. Another period of activity then began and lasted until the civil war, during which time over \$1,600,000 was laid out chiefly on roads in the Territories. From that time to this only a few military roads have been made, and of late years nothing has been done in the way of national aid, save the building of roads in the District of Columbia, in national cemeteries, and on reservations.

INTRODUCTION AND DEVELOPMENT OF STEAM RAILROADS.

The work of building national highways, it will be observed from the foregoing, progressed but slowly, and before much had been accomplished in this direction steam railroads were introduced. It was seen at once that this form of transportation would be far superior to the old method, and many people believed that railroads would eventually do away with the need of public highways. The national highways were, therefore, abandoned, and for several decades thereafter the public roads were almost completely neglected, while private capital undertook the construction of railroads.

The railroad had its birth in the United States on the Fourth of July, 1828. On that day the ceremony of breaking ground for the Baltimore and Ohio Railroad was performed by Hon. Charles Carroll, who was at that time the only surviving signer of the Declaration of Independence. From the small section that was operated at first by horse power has grown a system which places this country in the front rank in the character and extent of its railroads.

The mania for building railroads soon began to spread; speculators again came to the front, as they had done when turnpike building was so popular. Railway lines were projected which, had they all been built, would have far surpassed the number now in actual operation. Seven years after the commencement of the construction of the Baltimore and Ohio, over 1,000 miles of railroads were in operation in the United States, and to-day they penetrate nearly every section of our land.

Thus, the rapid development and extension of railways has, to a large extent, monopolized the thoughts, energies, and finances of the people, and tended to exclude consideration of the no less important source of national development, the public highways.

There must, however, be a limit to the building of railroads. With all our railroads, the transportation problem has not yet been solved. Indeed, the building of so many railroads has made it more necessary than ever that the primary means of transportation, the country road, should be improved. Ninety-nine per cent of all the commerce of the United States which is transported by steam is carried for some distance over the public thoroughfares, and "it costs as much in some cases to haul goods to or from the railway station over the country road as it does to transport by steam the same amount of goods from ocean to ocean or from continent to continent."

DIFFICULTIES OF TRANSPORTATION AND OF TRAVEL.

For many years after the introduction of railroads so little attention was given to the construction and maintenance of the public highways that their condition in most places became even more deplorable than ever. The local roads as well as the interstate turnpikes became practically impassable. As an illustration of these conditions the following facts are cited:

When agricultural machinery began to be manufactured at Walnut Grove, Va., great difficulty was experienced in procuring some of the material which had to be brought from a distance. Neither was it easy, when the machines were once manufactured, to get them to market. Sickles were made 40 miles away, but as there were no railroads and but few highways fit for wagons, the blades, 6 feet long, had to be carried on horseback. It was soon realized that while reapers were luxuries in Virginia and the East, they were a necessity in Ohio and Illinois and on the plains of the great West. When it was discovered that the West was the natural market for these agricultural machines, the next and most difficult question was that of getting them there. The question was finally solved by shipping the first consignment, in 1844, by wagon trains from Walnut Grove to Scottsville, Va., then down the canal to Richmond, thence by water down the James River into the Atlantic and around Florida into the Gulf of Mexico, thence by way of New Orleans up the Mississippi and Ohio rivers to Cincinnati, Ohio.[1]

When Charles Dickens visited America in 1842 he had occasion to travel by stagecoach from Cleveland to Sandusky, Ohio. His

[1] Men of Achievement, Inventors, by P. S. Hubert, jr.

FIG. 1.—THE ROLLED FOUNDATION OF AN OBJECT-LESSON ROAD BUILT AT HOT SPRINGS, VA., UNDER THE AUSPICES OF THE OFFICE OF PUBLIC ROAD INQUIRIES OF THE DEPARTMENT OF AGRICULTURE.

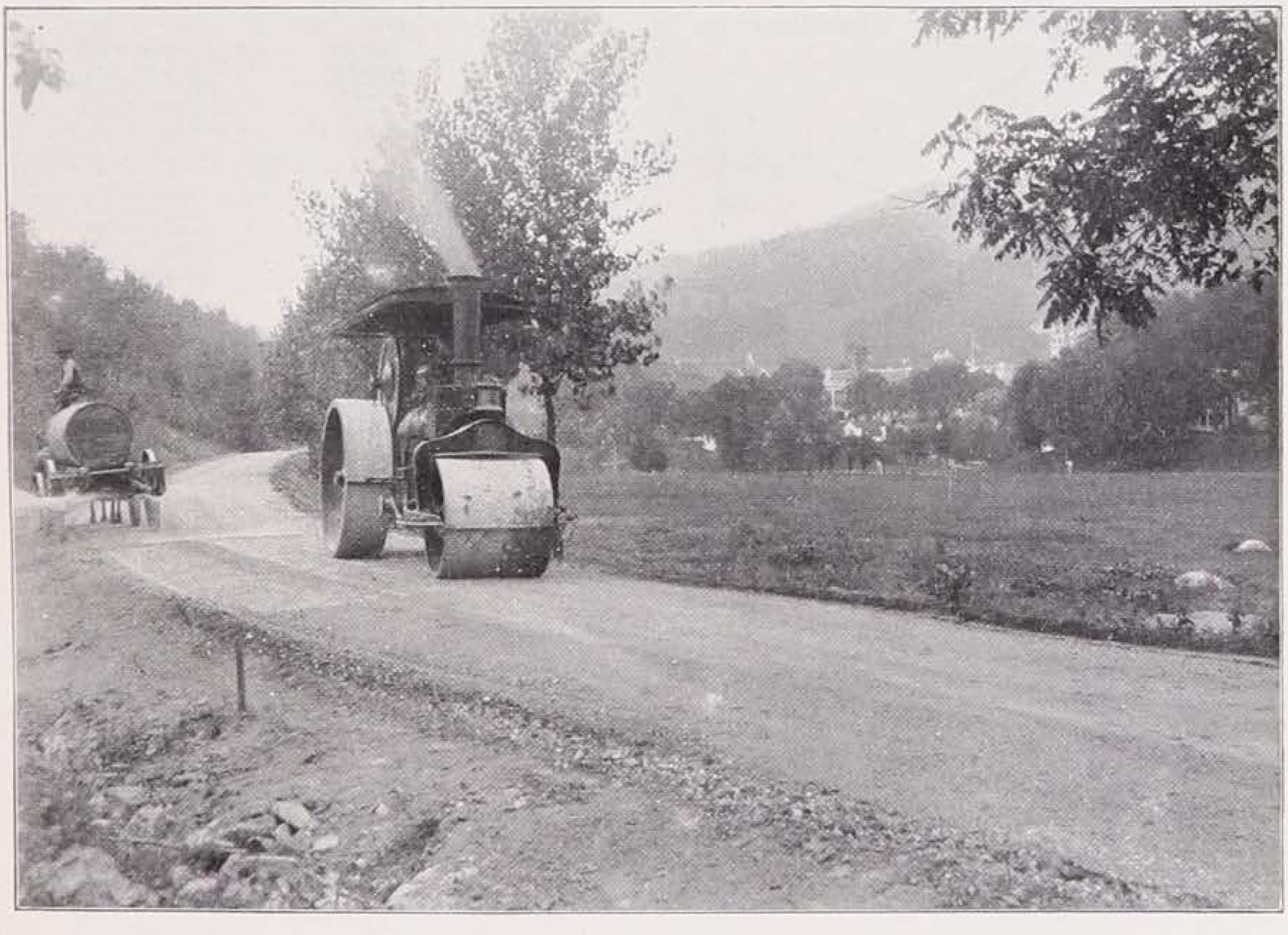


FIG. 2.—FINISHING TOUCHES TO THE SAMPLE ROAD BUILT AT HOT SPRINGS, VA., UNDER THE AUSPICES OF THE OFFICE OF PUBLIC ROAD INQUIRIES OF THE DEPARTMENT OF AGRICULTURE.

description of part of this journey can be used here to good purpose in describing the condition of many of the public roads of that day:

At one time we were all flung together in a heap at the bottom of the coach, and at another we were crushing our heads against the roof. Now, the coach was lying on the tails of the two wheelers; and now it was rearing up in the air in a frantic state, with all four horses standing on the top of an unsurmountable eminence. * * * The drivers on these roads, who certainly got over the ground in a manner which is quite miraculous, so twist and turn the team about in forcing a passage, corkscrew fashion, through the bogs and swamps, that it was quite a common circumstance on looking out of the window to see the coachman with the ends of a pair of reins in his hands, apparently driving nothing, or playing at horses, and the leaders staring unexpectedly at one from the back of the coach, as if they had some idea of getting up behind. A great portion of the way was over what is called a corduroy road, which is made by throwing trunks of trees into a marsh and leaving them to settle there. The very slightest of the jolts with which the ponderous carriage fell from log to log was enough, it seemed, to have dislocated all the bones in the human body. It would be impossible to experience a similar set of sensations in any other circumstances, unless, perhaps, in attempting to go up to the top of St. Paul's in an omnibus. Never, never once that day was the coach in any position, attitude, or kind of motion to which we are accustomed in coaches. Never did it make the smallest approach to one's experience of the proceedings of any sort of vehicle that goes on wheels.

This description also serves to illustrate the condition of the country roads, except in a few wealthy communities, twenty or twenty-five years ago. Kentucky was famous for her fine roads a generation ago. Even before the Eastern States had made any decided progress in this direction the State of Kentucky aided the construction of turnpikes by large county and State appropriations. Few States have been more liberal in promoting the building of better highways than Kentucky. The wretched condition of the country roads as well as the ever-increasing need for better ones did not, however, begin to attract widespread attention until something over ten years ago, but, although the movement is yet young in years, the agitation has already led to a general crusade which foreshadows thorough reformation.

ESTABLISHMENT OF THE OFFICE OF PUBLIC ROAD INQUIRIES.

Some road reformers think, as thought many of the founders of the Republic, that the General Government should aid in the building of the principal roads. This idea, however, has met with little encouragement; but out of the agitation has grown a law, passed by Congress in 1893, providing for an office in the Department of Agriculture to collect and disseminate information on the road subject, to conduct investigations, inquiries, and experiments regarding road materials and road construction, and to encourage, by object lessons and otherwise, the building of better roads. (Pl. XIV.) Twenty bulletins and thirty-three circulars containing information of great value to good-roads reformers as well as to good-roads builders have been published by the Office of Public Road Inquiries, and the usefulness of such a good-roads propaganda seems to have been fully demonstrated.

PROGRESS OF THE MOVEMENT IN THE STATES FOR GOOD ROADS.

More than half the States have passed new and progressive road laws, and many hundreds of miles of good roads have already been built under the influence of the new conditions of administration, finance, and construction. The general trend of legislation enacted in these States is as follows: More rigid provisions for carrying out the old systems without radical change in the systems themselves; more liberal tax levies; substitution of money tax instead of labor; local assessment, according to benefits, for the construction of new roads; construction by townships, counties, and districts, with power to issue bonds; State highway commissions; provisions for working convicts; regulations compelling and encouraging the use of wide tires; State aid to road building; construction of State roads.

New Jersey was the first State to take any radical step toward the improvement of her public highways. Her State-aid law was passed in 1891. It provides that on petition of the owners of two-thirds of the lands bordering any public road, not less than a mile in length, asking that the road be improved and agreeing to pay 10 per cent of the cost, the county officials shall improve the road, one-third of the expenses to be borne by the State, if the road is brought to the standard fixed by the State commissioner of public roads, and the balance ($66\frac{2}{3}$ per cent) by the county. The State's expenditures for such improvements in any one year are limited to \$150,000, while the county is limited to one-fourth of 1 per cent of its assessed valuation. At this rate the law makes possible the expenditure of \$450,000 a year, and at \$3,000 per mile this builds 150 miles of road. Ten miles of road were built in 1892, 25 miles in 1893, 60 miles in 1894, and since 1895 the applications for new roads have been far in excess of the limit prescribed by law. (Pl. XV.)

Under this law about 450 miles of improved road have already been built in New Jersey, the State's portion of the expense being about \$715,800. The counties and towns have built out of their own treasuries 450 more miles, which brings the total mileage of improved roads for the State up to 900. These roads cost at first about \$6,000 per mile, but on account of the reduction in the price of materials and the increase of labor-saving machinery the cost has been reduced to about half this amount. The farmers, who at first strongly opposed the law, are now equally enthusiastic for it, and more roads are being petitioned for than can possibly be built in many years out of the limited State appropriation. The system seems to be popular with all classes, and it is being carefully considered by the legislatures of other States. Its principles have been adopted by Massachusetts, Connecticut, Rhode Island, New York, and California. These laws, of which State aid is the principle feature, are regarded by the active advocates of road reform as affording a satisfactory solution of the problem.

FIG. 1.—TYPE OF ROAD IN NEW JERSEY BEFORE IMPROVEMENT.

FIG. 2.—TYPE OF ROAD IN NEW JERSEY AFTER IMPROVEMENT.

FIG. 1.—TYPE OF ROAD IN MASSACHUSETTS BEFORE IMPROVEMENT.

FIG. 2.—TYPE OF ROAD IN MASSACHUSETTS AFTER IMPROVEMENT.

Massachusetts, like New Jersey, also has adopted a system of road improvement which, it is believed, will result in a few years in securing to that State highways that will be second in excellence to none in the United States and equal to some of the best in the Old World. The State has a permanent highway commission, consisting of three persons. Each year this commission is allowed to spend $600,000 for building and maintaining roads, which are called State roads. The law provides that not more than 10 miles of road can be built in any one county in a year and that within six years after the construction of any State road the county in which the road is situated must pay to the State one-fourth of the money expended. Nearly 300 miles of excellent roads have been built in Massachusetts under this new system, the average cost per mile of which was about $9,000. (Pl. XVI.)

Connecticut has made rapid progress in building highways during the last five years. It now has a highway commission, which was provided in 1895–96 with $450,000 and in 1897–98 with $400,000 for road improvement. In 1895–96 the State paid one-third the expense of constructing the roads, the town one-third, and the county the remainder, but in 1897–98 the State increased its part of the expense to one-half, the other half being borne by the towns. The amount of work accomplished is shown by the fact that in the two years last named the entire State appropriation was applied for by the towns, and this was done without any county assistance.

Although the Rhode Island commissioner of highways does not favor State aid, as adopted in the adjacent States, the legislature has at his suggestion passed a law which enables him to build a half-mile sample of good macadamized highway in each town. These permanent object lessons are of great benefit to the towns where good highways have not been built, and are conducive to more liberal appropriations for new roads, as well as more thorough construction, when the local authorities choose to carry the work forward. Out of 2,240 miles of highways in Rhode Island, about 500 miles have been improved by the use of gravel or stone.

The legislature of New York passed a bill last year which provides that the State's share in the improvement of highways shall be 50 per cent of the cost, the county's share 35 per cent, and the town's share the remainder. The boards of supervisors are given the right to decide what roads, if any, are to be improved, thus making the matter of road improvement entirely optional. No new offices were created, the State engineer being placed in charge of all road work. The law seems to give satisfaction; several miles of new roads have been built, and work is still in progress, under its provisions.

The legislature and people of California have not been idle in the work for good roads nor blind to the needs of the State in this respect. Up to a few years ago some of the convicts had been supported in comparative idleness at the expense of the State, while others had been utilized in direct competition with free labor. In 1895 the legislature decided, at the suggestion of Gen. Roy Stone, to utilize convict labor in preparing road materials; a bill was passed providing for a highway commission and for the construction of a rock-crushing plant on one of the State prison grounds. Since that time the convicts have been turning out upward of 100,000 tons of crushed trap rock annually. Much of this material has been given to the counties as the State's contribution toward the improvement of the leading thoroughfares.

North Carolina, Delaware, Iowa, New Jersey, New York, Tennessee, and other States also have laws providing for the use of convict labor in improving the highways. North Carolina has made greater progress and has built more miles of roads under this system than any other State. Thus, one might, if space permitted, go through the whole list of States and find evidences of great progress in road improvement. Governor Mount, of Indiana, for instance, says that his Commonwealth is provided with 58,000 miles of graded, graveled, and piked highways, over 8,000 miles of which are comparable with the best roads of France. The public is now more thoroughly aroused to the importance of the movement for better roads than ever before, and more roads and better roads have been built in the United States in 1899 than in any previous year in its history.

The agitation which has become so universal will surely result in a well-defined public sentiment that will soon overcome all obstacles. With the new century, the good-roads movement is likely to receive valuable aid from the owners of horseless vehicles, already not uncommon on our thoroughfares. The aid of these new allies, added to that of the farmer, with his great pecuniary interest in the question, to say nothing of the army of wheelmen already enlisted in the cause, promises well for a rapid spread of the movement throughout the country.

DAIRY DEVELOPMENT IN THE UNITED STATES.

By Henry E. Alvord,
Chief of Dairy Division, Bureau of Animal Industry.

THE PRESENT FIELD OF THE DAIRY INDUSTRY.

No branch of agriculture in the United States has made greater progress than dairying during the nineteenth century. No other has received more direct benefit from the art of invention, the teachings of modern science, and the intelligent practice of skilled operators. Cooperative and commercial organizations have been formed to conduct the business locally and to guard its general interests. State laws and appropriations of money have been made to foster and promote this industry. Dairying has become the specialty of districts of wide area in different parts of the country. It is now regarded as among the most progressive and highly developed forms of farming in the United States.

The greater part of this country has been found so well adapted to dairying that its extension has more than kept pace with the opening and settlement of new territory. A belief was long entertained that successful dairying in America must be restricted to narrow geographical limits, constituting a "dairy belt" lying between the fortieth and forty-fifth parallels of latitude and extending from the Atlantic Ocean to the Missouri River; the true dairying districts were thought to be in separated sections, occupying not more than one-third of the area of this belt. These ideas have been exploded. It has been proved that good butter and cheese can be made, by proper management, in almost all parts of North America. Generally speaking, good butter can be made wherever good beef can be produced. Advantages unquestionably exist in the climate, soil, water, and herbage of certain sections, but these factors are largely under control, and what is lacking in natural conditions can be supplied by tact and skill. So that, while dairying is intensified, and constitutes the leading agricultural interest over large areas where the natural advantages are greatest, the industry is found well established in spots in almost all parts of the country and developing in unexpected places and under what might be considered as very unfavorable conditions.

DAIRYING DURING THE COLONIAL PERIOD AND AT THE PRESENT TIME.

Dairying was practiced in this country in colonial times, and butter and cheese are mentioned among the early exports from the settlements along the Atlantic coast; but this production was only a feature of general and pioneer farming. Dairying as a specialty did not appear in the United States to any extent until well along in the nineteenth century. The dairy history of the country is therefore identical with its progress in the present century. This progress has been truly remarkable. The wide territorial extension; the immense investment in lands, buildings, animals, and equipment; the great improvement in dairy cattle; the acquisition and diffusion of knowledge as to economy of production; the revolution in methods and systems of manufacture; the general advance in quality of products; the wonderful increase in quantity; the industrial and commercial importance of dairying, all constitute a prominent feature in the material progress of the nation.

DAIRYING DURING THE EARLY PART OF THE CENTURY.

During the early part of the century the keeping of cows on American farms was incident to the general work. The care of milk and the making of butter and cheese were in the hands of the women of the household, and the methods and utensils were crude. The average quality of the products was inferior. The supply of domestic markets was unorganized and irregular. The milch cows in use belonged to the mixed and indescribable race of "native" cattle, with occasionally a really good dairy animal appearing singly, almost by accident, or, at the best, as one of a family developed by some uncommonly discriminating yet unscientific breeder. The cows calved almost universally in the spring, and were generally allowed to go dry in the autumn or early winter. Winter dairying was practically unknown. As a rule, excepting the pasture season, cattle were insufficiently and unprofitably fed and poorly housed, if at all. It was a common thing for cows to die of starvation and exposure, and it was considered no disgrace to owners to have their cattle "on the lift"[1] in the spring. In the Eastern and Middle States the milk was usually set in small shallow earthen vessels or tin pans for the cream to rise. Little attention was paid to cooling the air in which it stood in summer or to moderating it in winter so long as freezing was prevented. The few who scalded fresh milk had no idea of the true reason for so doing or why beneficial effects resulted. The pans of milk oftener stood in pantries and cellars or on kitchen shelves than in rooms specially constructed or adapted to the purpose. In southern Pennsylvania and the States farther south spring houses were in vogue; milk received

[1] A common expression in years past in some localities, indicating the actual necessity of human aid to raise emaciated animals to their feet.

FIG. 1.—BUTTER MAKING—THE OLD WAY.

FIG. 2.—BUTTER MAKING—THE NEW WAY.

care, and setting it in earthen crocks or pots, standing in cool, flowing water, was a usual and excellent practice. Churning the entire milk was very common. This is still done to some extent in the Southern States, where butter is made every morning and where all the milk is buttermilk. In seasons of scarcity of milk there was no butter. In the Northern States there were some instances where families were supplied with butter weekly during most of the year, and with an occasional cheese, directly from the producers. But the general farm practice was to "pack" the butter in firkins, half firkins, tubs, and jars, and let the cheese accumulate on the farm, taking these products to market only once or twice a year. Not only were there as many different lots and kinds of butter and cheese as there were producing farms, but the product of a single farm varied in character and quality according to season and other circumstances. Every package had to be examined, graded, and sold upon its merits. It was usual for half the butter in market to be strong, if not actually rancid, and for cheese to be sharp. With the products largely low in grade, prices were also very low. (Pl. XVII.)

DAIRYING DURING THE MIDDLE OF THE CENTURY.

The above conditions continued without material change up to the middle of the century. Some improvement was noticeable in cattle and appliances, and in some sections dairy farming became a specialty, although not in a marked degree. Herkimer County, N. Y., is probably the best example of early dairy districts in this country. Of this county X. A. Willard wrote (in 1870) as follows:

> Cheese making began here more than sixty years ago. For upward of twenty years its progress was slow and the business was deemed hazardous by the majority of farmers, who believed that overproduction was to be the result of making a venture upon this specialty. The fact, however, gradually became apparent that the cheese makers were rapidly bettering their condition and outstripping in wealth those who were engaged in grain raising and a mixed husbandry. About the year 1830 dairying became general in the towns of Herkimer County north of the Mohawk, and some years later spread through the southern part of the county, gradually extending into Oneida and adjoining counties. Up to this period and for several years later little or no cheese was shipped to Europe. It was not considered fit for market till fall or winter. It was packed in rough casks and peddled in the home market at 5 to 8 cents a pound.

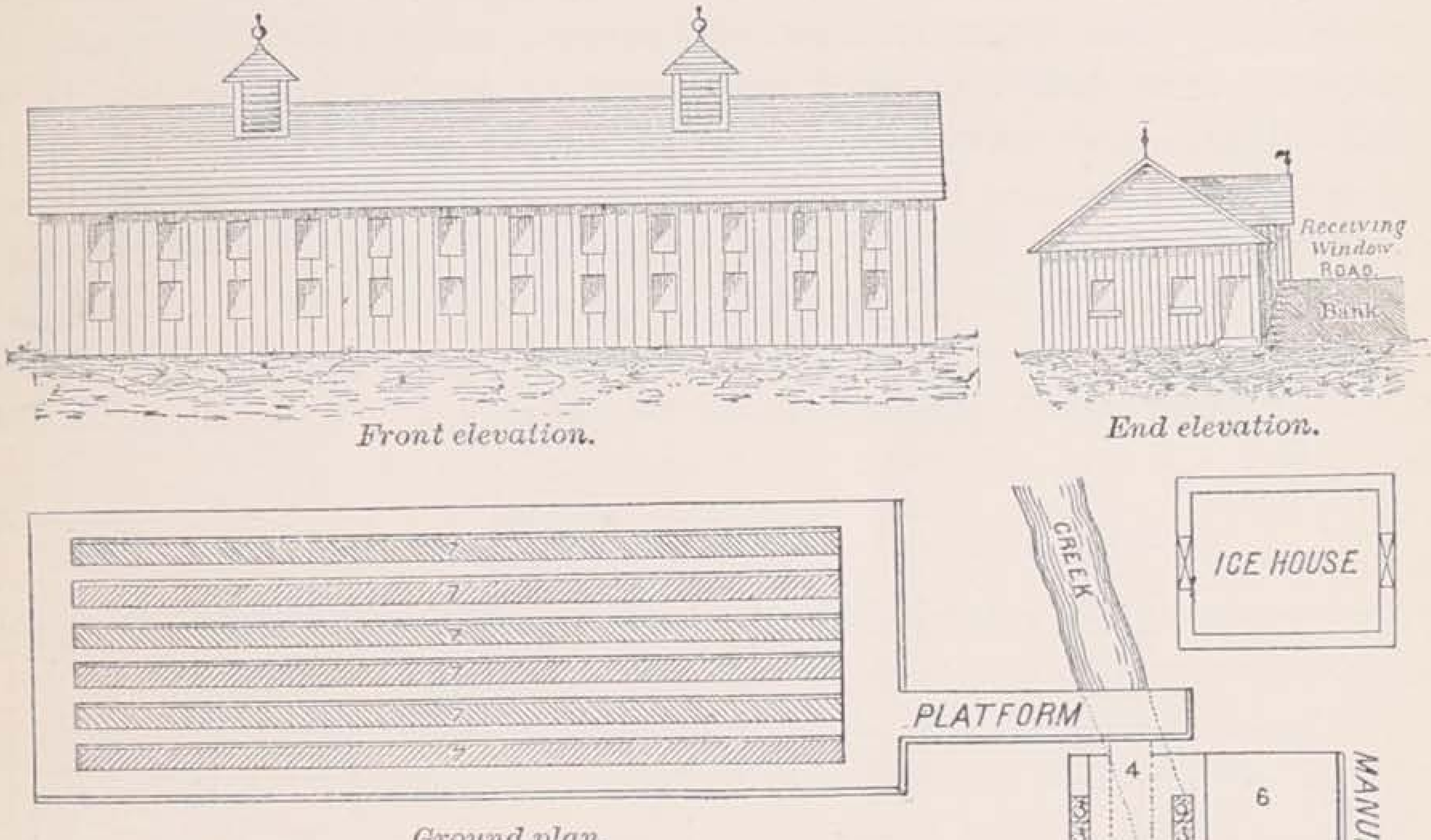
All the operations of the dairy continued rude and undeveloped even in these "dairying districts." The cows were milked in the open yard, and the curds were worked in homemade tubs and pressed in log presses. Everything was done by guess; there was no order, no system, no science in dairy operations. The cheese-making section gradually embraced the central and western portions of New York and the adjacent parts of Pennsylvania and Ohio, and the total production became large. Toward the middle of the century the gross supply of cheese was in excess of domestic demand, and cheese exports from the United States, mainly to Great Britain, ranged from 3,000,000 to 17,000,000 pounds a year. With the growth of cities and towns the business of milk supply increased and better methods prevailed. Yet, prior to the year 1850 no city had received any part of its milk supply by railroad transportation; near-by producers met all existing demands by hauling in their own vehicles. Butter making for home use and in a small way for local trade was common wherever cows were kept, and in some places there was a surplus sufficient to be sent to the large markets. Vermont and New York became particularly noted for butter production. "Franklin County butter," from counties of this name in those two States and in Massachusetts, was the favorite in New England markets, and the fame of "Orange County" and "Goshen" butter, from southern New York, was still more extensive.

DAIRYING DURING THE THIRD QUARTER OF THE CENTURY.

The twenty-five years following 1850 was a period of remarkable activity and progress in the dairy interests of the country. At first the agricultural exhibitions or "cattle shows," which were comparatively new and popular, and the enterprise of importers turned attention toward the improvement of farm animals; breeds of cattle noted particularly for dairy qualities were introduced and began to win the favor of dairy farmers. Then the early efforts at cooperation in dairying were recognized as successful, and were copied until the cheese factory became an established institution. Once fairly started in the heart of the cheese-making district of New York, the factory system spread with much rapidity. The "war period" lent additional impetus to the forward movement. The price of cheese, which was 10 cents per pound and less in 1860, rose to 15 cents in 1863 and to 20 cents and over in 1865. The foreign demand increased also, and the yearly cheese exports rose from 10,000,000 pounds in 1850 to 15,000,000 in 1860 and to almost 50,000,000 in 1865. Ten years later over 100,000,000 pounds were exported.

ESTABLISHMENT OF CHEESE AND BUTTER FACTORIES.

Although several earlier instances of associated dairying have been authenticated, which were locally successful, it is generally conceded that the credit of establishing the first real cheese factory, which served as a model and incentive to others (fig. 10), belongs to Jesse Williams, of Oneida County, N. Y. Mr. Williams lived upon his farm, near Rome. He was an experienced and skillful cheese maker, and his dairy had such a good reputation and its product was so eagerly sought at prices above the average that he increased his output of cheese by adding to his own supply of milk that from the herd of a son located upon a farm near by, and then from other neighbors. This idea of bringing together daily the milk from several neighboring farms, to be made into cheese at one place by a skilled operator, was



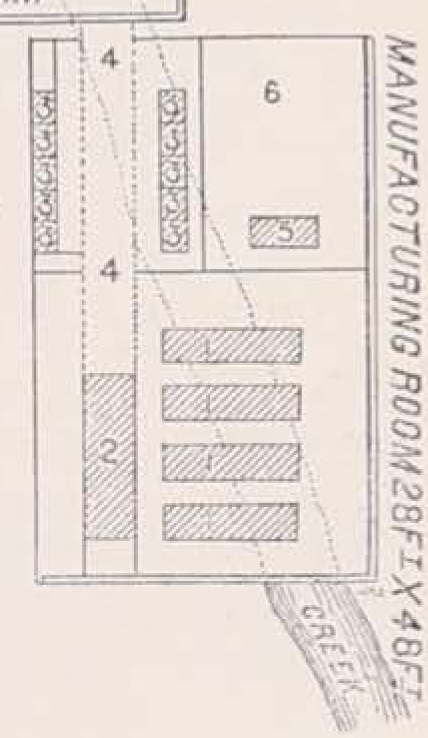


FIG. 10.—Elevations and plan of one of the first cheese factories built in the United States.

the germ from which sprang the cheese-factory system of the United States. Mr. Williams began working on this plan in 1851. He was so successful that a special building was erected the next year and fitted up with the best apparatus obtainable. The effect of this good example and the early extension of the factory system is shown by the following table, which gives the number of factories built and put into operation in New York annually during the years stated:

Number of cheese factories established in the State of New York annually, 1854–1866.

Year.	Factories.	Year.	Factories.
1854	4	1862	25
1855	2	1863	111
1856	3	1864	210
1857	3	1865	52
1858	4	1866	46
1859	4	Total in 1866	499
1860	17		
1861	18		

Cheese factories were soon started in Pennsylvania and Ohio, and then in other States, East and West. In 1869 the number in the whole country exceeded 1,000, and from that time the cooperative, or factory, system practically superseded the making of cheese on farms.

Making butter in quantity from milk or cream collected from numerous farms soon followed as the next advance in American dairying. Such establishments are properly butter factories, but the name of "creamery" has been generally adopted, and is not likely to be changed. The first creamery was built by Alanson Slaughter, near Wallkill, Orange County, N. Y., in the year 1861. The milk from 375 cows was received here daily. In Illinois the first cheese factory was started in 1863 and the first creamery in 1867. In Iowa these respective dates were 1866 and 1871. During the earlier years of their operation it was quite common for both butter and cheese to be made at the creameries at different times, or butter and skim cheese at the same time.

SOME FEATURES OF THE FACTORY SYSTEM OF DAIRYING.

The effect of the establishment of cheese and butter factories, comparatively new in kind, is to transfer the making of butter and cheese from the farm to the factory. Originating in this country, although now extensively adopted in others, the general plan may be rightly called "The American system of associated dairying." It constitutes one of the notable and important landmarks in the progress of dairying during the present century. The early cheese factories and creameries were purely cooperative concerns, and it is in this form that the system has usually extended into new territory, whether for the production of butter or cheese. The cow owners and producers of milk cooperate and share, upon any agreed basis, in organizing, building (or renting and refitting), equipping, and managing the factory and disposing of its products. The farmers interested as joint owners, and all who contribute milk or cream, are called the patrons. The operations are managed by a committee or board of directors chosen by and from the patrons. If the business is large enough to warrant the expense, the immediate supervision of the concern and all its interests is intrusted to a single manager, employed by the board. In a factory of this kind all expenses are deducted from the gross receipts from sales and the remainder is divided pro rata among the patrons upon the basis of the raw material contributed. Another plan is for the plant to be owned by a joint stock company, composed largely, if not wholly, of farmers, and milk or cream is received from any satisfactory producer. In this case interest on the property or capital is usually allowed and included in the current expenses. The management is otherwise the same; the stockholders receive a fixed rate of interest on their investment and the dividends to patrons depend upon their deliveries of milk or cream and the fluctuations of the market for the factory products. The proprietary plan is also common, being managed much like any other factory; the proprietor or company buys the milk or cream from the producers at prices mutually agreed upon from time to time and assumes all the expenses, risks, and returns of the business. Another way is for the factory, whether owned and managed by a company of farmers (probably themselves patrons) or by outsiders, to bear all expenses, make and sell the butter and cheese at a fixed charge per pound, and divide the net proceeds of sales as on the purely cooperative plan. All these plans are varied and modified in practice. Fig. 11 shows the ground plan of the first creamery in this country.

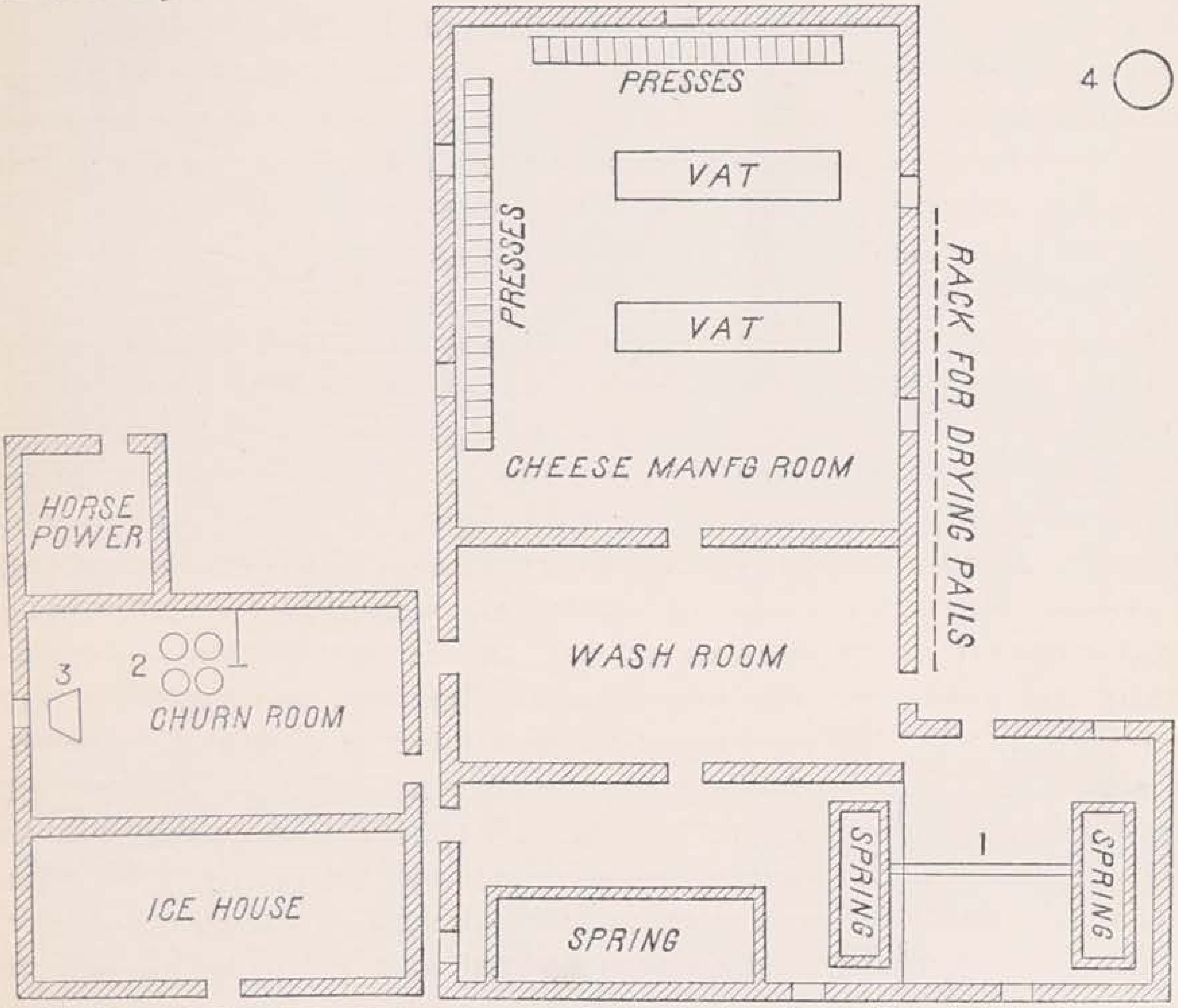


FIG. 11.—Ground plan of the first creamery, or butter factory, in the United States (provisions for cheese making, included): 1, water pipe; 2, churns; 3, butter worker; 4, whey cistern.

METHODS OF MANAGEMENT OF CHEESE AND BUTTER FACTORIES.

Independent of the matters of ownership, organization, and control, the factories and creameries differ much in methods of management and of settlement with patrons. Great progress in these particulars has been made since the introduction of the system. The first establishments received milk from patrons daily and sometimes twice a day. From near-by farms the milk was often warm from the cow at time of delivery. The milk was then kept in large vats (for cheese making) or in immense shallow pans in a cooling and creaming room until skimmed. Abundant room and expensive receptacles were nec essary at the creamery. Then, for butter making, deep setting of the milk in cool water was adopted. The creameries were provided with pools or stationary vats below the floor level. Through these, cool water flowed from springs near at hand, and in them the milk was set in "shotgun" cans (fig. 12), immediately after arrival, for cooling and for cream to form. The pools were 18 or 20 inches deep, with racks at bottom to hold cans. The tin cans were 22 inches deep and 8 inches in diameter and filled so that when in the pool the top of the milk was just below the surface of the water. Springs with abundant flow and having a natural temperature of 48° to 56° F. were regarded as highly desirable. Afterwards came the method of mechanical cream separation (to be later described) in place of "setting," or the gravity system. Another radical change, which began about 1875, was to set and skim the milk on the farms and haul only cream to the factories. Agents from the creameries, with suitable teams and carrying cans, drove from farm to farm and gathered the cream. Hence, the name of "gathered-cream factories" for establishments of this class. This kind of factory is still the favorite in some good butter districts, and it has very decided merits. The earliest factories and creameries paid for milk by the quart or gallon and at the same price, all lots of equal bulk being regarded of equal value. The first step in advance on this line was to buy or credit milk by weight, but still all at the same price. On the gathered-cream plan, equal bulk measures of cream were long regarded as of like value, and this is still practiced to some extent. The most modern and approved plan is to pay for the milk or cream received by factory or creamery according to the pounds of fat it actually contains as experimentally determined. This will be referred to later. At first it was considered sufficient to have 200 cows tributary to a factory, and patrons were expected to be located within a mile or two, and 4 or 5 miles was the maximum haul. Larger factories were soon favored as more economical, and very large ones have been lately put in operation, each receiving the daily product of thousands of cows. Milk and cream is hauled twice as far as formerly to patronize a factory, and often by cooperation among the farmers along a "route." All patrons are now expected to cool their milk thoroughly before it leaves the farm. In the latest form of creamery management, cream is collected over many square miles of territory and transported long distances by rail to be made into butter at a central factory. (A modern creamery is shown in Pl. XVIII.)


FIG. 12.—"Shot-gun" setting can and cream dipper.

THE CONDENSED-MILK INDUSTRY.

The condensed-milk industry had its beginning coincident with the inauguration of the factory system for making butter and cheese. Some method of preserving milk had long been sought and numerous preparations of the article had been offered, but these failed to meet the requirements and win public favor. In 1846 experiments were

FIG. 1.—A PIONEER CREAMERY IN THE STATE OF SOUTH DAKOTA.

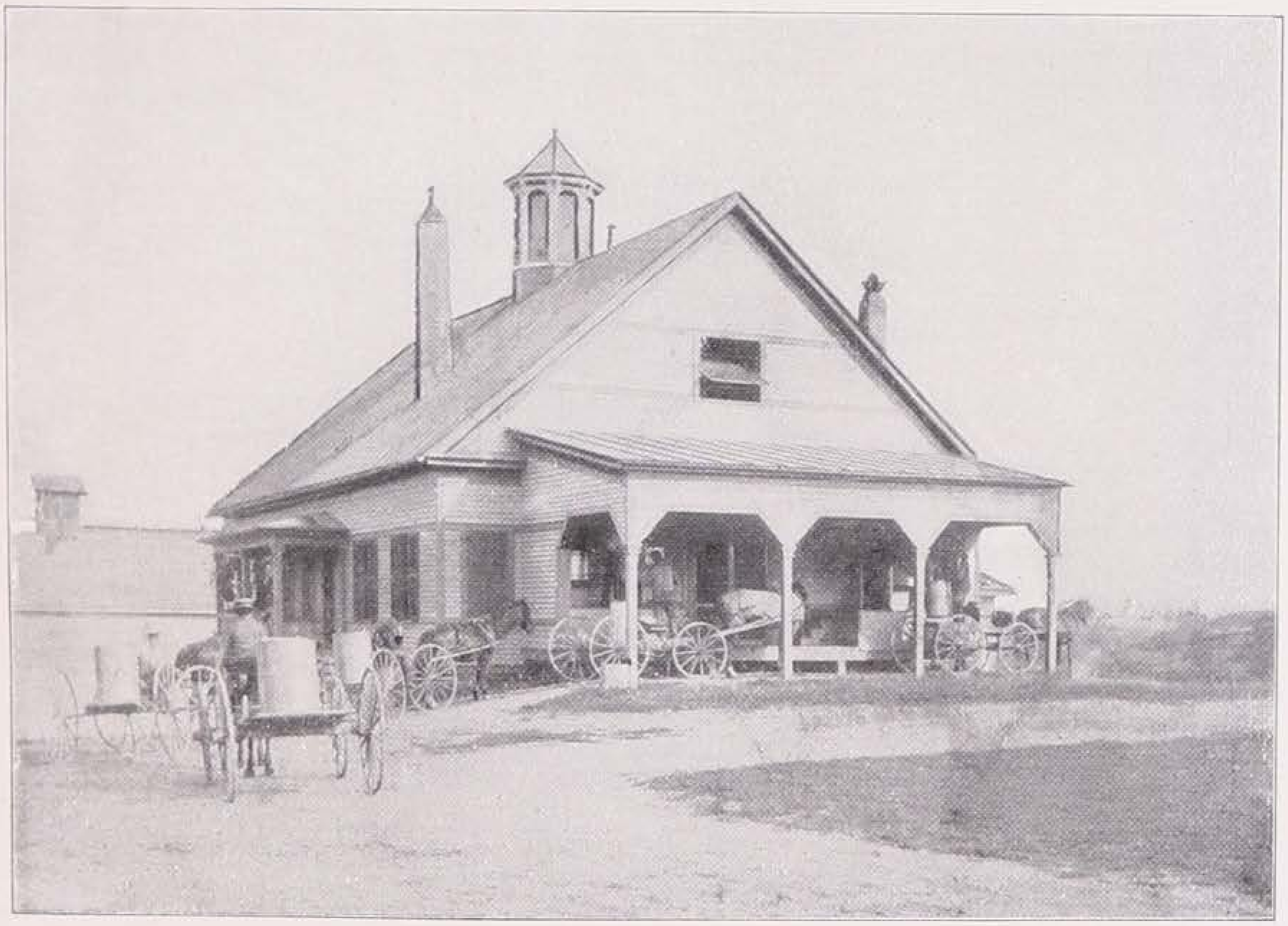


FIG. 2.—A MODERN CREAMERY IN THE STATE OF NEW YORK.

begun in New York by Mr. Gail Borden with a view of securing a preserved milk that was pure, wholesome, and palatable, capable of being transported long distances and kept for long periods in trying climates, and then serving as a satisfactory substitute for crude, fresh milk; but it was not until 1856 that he obtained results which have since popularized the product in every quarter of the globe. The previously prevailing ideas of a dry form of milk (desiccated, solidified, or powdered) were abandoned, and it was decided that a semiliquid state was the best form for preservation. The correctness of this decision is attested by the fact that, extensive as the industry now is and numerous as are the commercial brands, all condensed milk is still prepared under substantially the system then originated. This applies to the unsweetened as well as to the sweetened article, for "plain condensed milk" was first introduced and put upon the market about the year 1861. It was then mainly in open vessels and intended for early use. At that time condensed milk in both forms had become well known, and four or five factories were in operation, each producing about 5,000 one-pound cans per day. For the year 1879 the production of condensed milk in the United States was reported as 13,000,000 pounds and for 1889 as 38,000,000 pounds.

APPLICATION OF MECHANICS TO THE DAIRY.

The third quarter of the century was also a period of unprecedented progress in the application of mechanics to the dairy. The factories

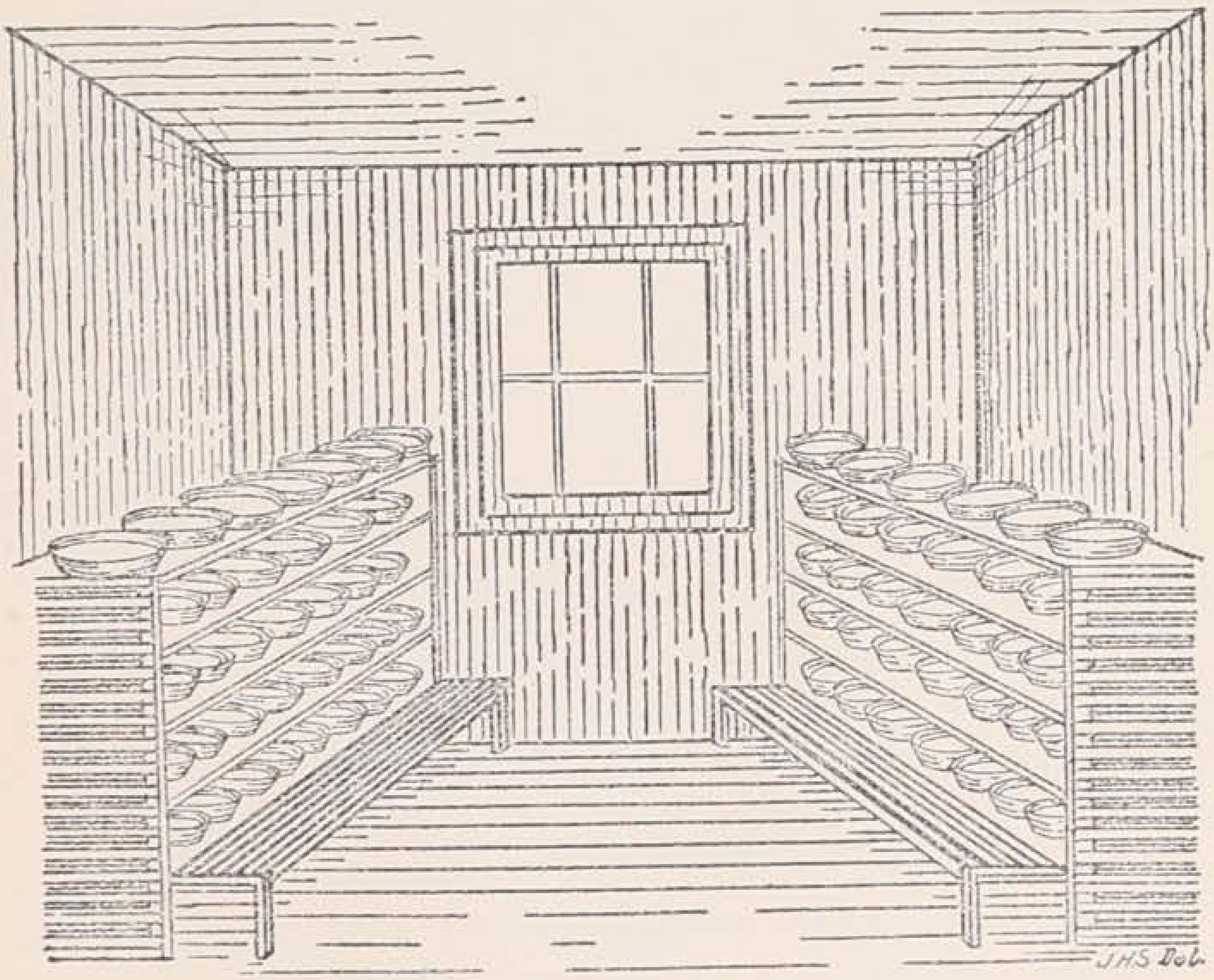


FIG. 13.—Milk room, with small shallow pans.

and creameries required new equipment, adapted to manufacture upon an enlarged scale, and equal attention was paid to the improvement of appliances for farm dairies. Shallow pans were changed in shape and greatly enlarged; some were made to hold 20 or 30 gallons, and had bottom and sides double for cooling or warming by the water jacket. (See figs. 13 and 14.) Then these big pans, and most others, disappeared in favor of deep setting. This system, in which deep

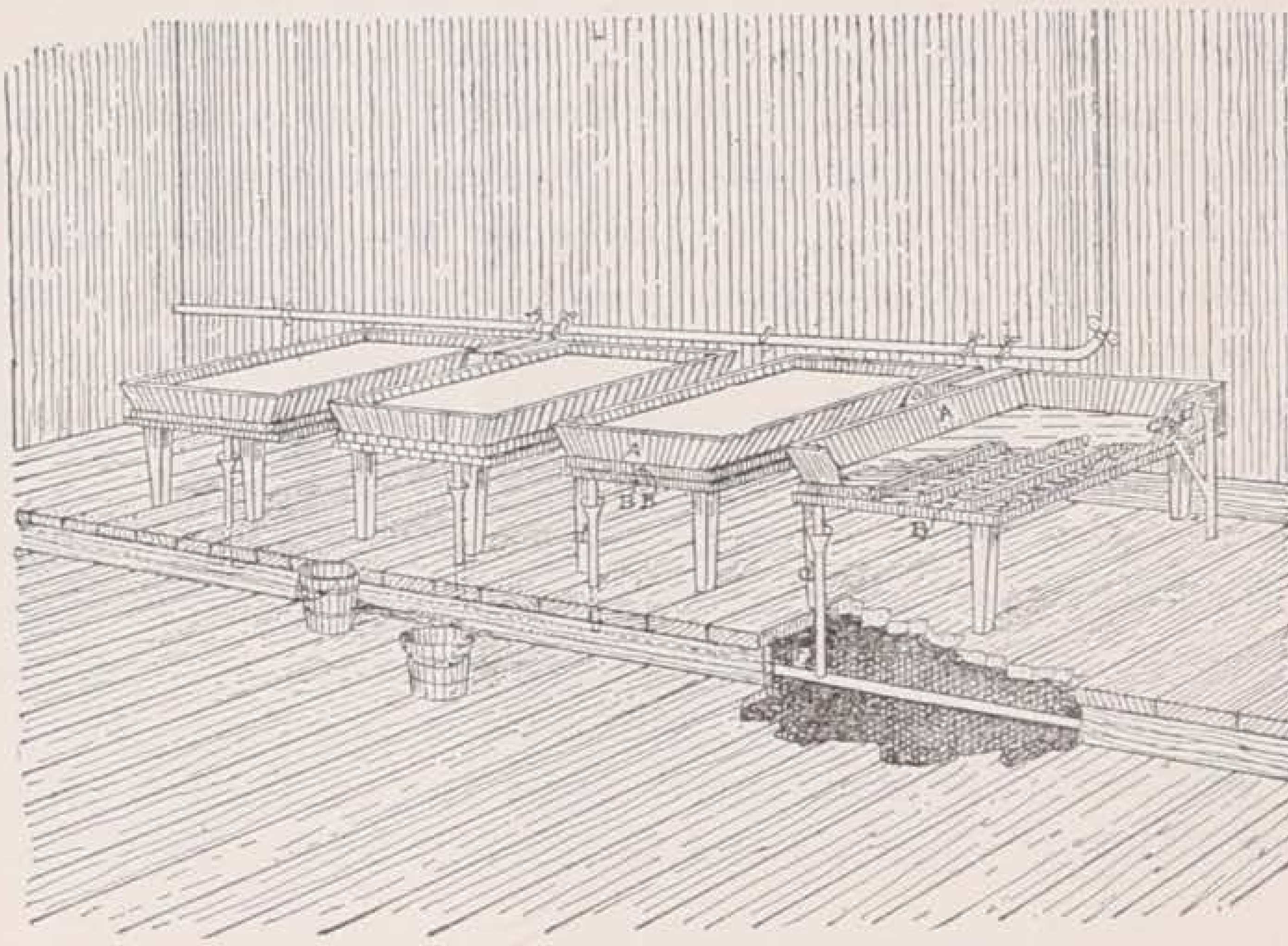


FIG. 14.—Large milk pans, open and shallow.

cans were used, set in cold water, preferably iced water, was introduced from Sweden, although the same principles had been in practice for generations in the spring houses of the South. Numerous creaming appliances, or creamers, were invented, based upon this

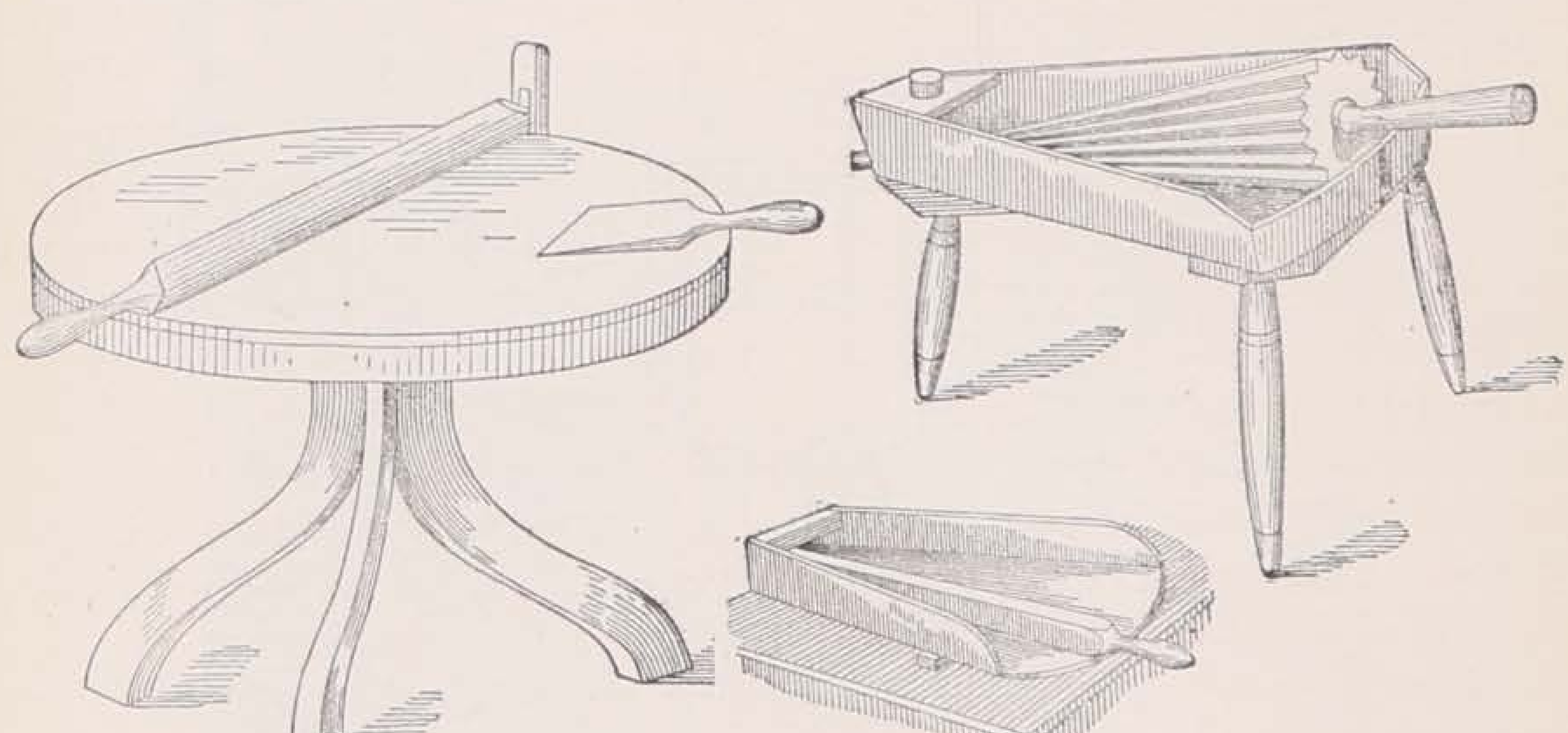


FIG. 15.—Patterns of hand butter workers.

system. Butter workers of various models, most of them employing the lever, or a crank and roller, took the place of the bowl and ladle and the use of the bare hand. Churns appeared of all shapes, sizes, and kinds, the general plan being to abolish dashers and substitute the agitation of cream for violent beating. About this time the writer made a search of the United States Patent Office records, which revealed the fact that forty or fifty new or improved churns were claimed annually, and, after about one-fourth were rejected, the patents actually issued provided a new churn every ten or twelve days for more than seventy years! This illustrates the activity of invention in the dairy line. It was admitted by all that at this period the United States was far in advance of any other country in the variety and excellence of its mechanical aids to dairying. (Fig. 15.)

ORGANIZATION OF DAIRYMEN'S ASSOCIATIONS.

The same period witnessed the organization of dairymen in voluntary associations for mutual benefit, the formation of clubs and societies of breeders of pure-bred cattle, and the appearance of the first American dairy literature of consequence in book form. The American Dairymen's Association was organized in 1863. Its field of activity was east of Indiana, and accordingly the Northwestern Dairymen's Association was formed in 1867. Both of these associations continued in existence, holding periodical conventions and publishing their proceedings for twelve or fifteen years. Then followed the formation of State dairy associations in Vermont (1870), Pennsylvania (1871), Wisconsin (1872), Illinois (1874), Iowa (1876), New York (1877), and other States, superseding the few pioneer societies, which, for the time, covered broader fields.

INTRODUCTION OF DAIRY CATTLE AND EFFORTS AT HERD IMPROVEMENT.

The Shorthorn breed led in the introduction of improved cattle to the United States, and for a long time the representatives of this race, imported from England, embraced fine dairy animals. Shorthorn grades formed the foundation, and an excellent one, upon which many dairy herds were built during the second and third quarters of the century, and much of this blood is still found in prosperous dairy districts. The period named was that of greatest activity in importing improved cattle from abroad; but Shorthorns have been so generally bred for beef qualities that the demand for them is almost exclusively on that line, and very few of the breed are now classed as dairy cattle. Ayrshires from Scotland, Holstein-Friesians from North Holland, and Jerseys and Guernseys from the Channel Islands, are the breeds recognized as of dairy excellence, and upon animals graded and improved from these the industry mainly depends. The first two breeds named are noted for giving large quantities of milk of medium quality; the other two, both often miscalled "Alderney," give milk of exceeding richness, and theirs is the favorite blood with butter makers. There are also the Brown Swiss and Simmenthal cattle from Switzerland, the Normandy breed from France, and Red-Polled cattle from the south of England which have dairy merit, but belong rather to what is called the "general-purpose" class. Associations of persons interested in maintaining the purity of the respective breeds have been formed since 1850, and they all record pedigrees and publish registers or herdbooks. Pure-bred herds of some of these different breeds are owned in nearly every State, and these animals aggregate 200,000 or 300,000. Their blood is so generally diffused that half-breeds or higher grades are very numerous wherever cows are kept for dairy purposes. Therefore, although pure-bred animals form less than 2 per cent of the working dairy herds, their influence is so great that it is probable the average dairy cow of the United States at the close of the century will carry nearly 50 per cent of improved blood. The breeding and quality of this average cow, and consequently her productiveness and profit, have thus been steadily advanced.

The progress made in this respect in fifty years has been remarkable. When improvement upon the native stock began, a cow that would make a pound of butter a day for two or three months was a local celebrity. Now and then a single animal made a really noteworthy record, like that of the Oakes cow, famous in Massachusetts about 1816. This cow gave 44 pounds of milk a day and made 467 pounds of butter during one season, but she was evidently a sport and failed to reproduce her equal. The first good record of definite herd improvement was made by Zadock Pratt, of Greene County, N. Y. By careful selection and culling he increased the average butter product of his 50 cows from 130 pounds for the year 1852 to 225 pounds in 1863; for seven years the average milk yield was 4,710 pounds per cow. About 1865, when good cows sold for $40 or less, an enterprising dairyman in New England advertised widely that he would pay $100 for any cow which would yield 50 pounds of milk a day on his farm for two or three consecutive days. Not an animal was offered under these conditions. The good dairy cow has now been so long bred to a special purpose that instead of the former short milking period, almost limited to the pasture season, it yields a comparatively even flow of milk during ten or eleven months in every twelve, and if desired the herd produces as much in winter as in summer. A cow that does not average 6 or 7 quarts of milk per day for three hundred days, being 4,000 to 4,500 pounds a year, is not considered profitable. There are many herds having an average yearly product of 5,000 pounds per cow, and single animals are numerous which give ten or twelve times their own weight in milk during a year. Quality has also been so improved that the milk of many a cow will make as much butter in a week as did that of three or four average cows of the mid-century. Whole herds average 300 to 350 pounds of butter a year, occasionally more, and authenticated records of cows giving 2 pounds a day are very numerous. Rivals to the Oakes cow may now be found frequently, often several in one bovine family, the dairy merit maintained and transmitted by judicious breeding; and although animals of such excellence are none too common, they no longer excite astonishment or incredulity. (Pl. XIX.)

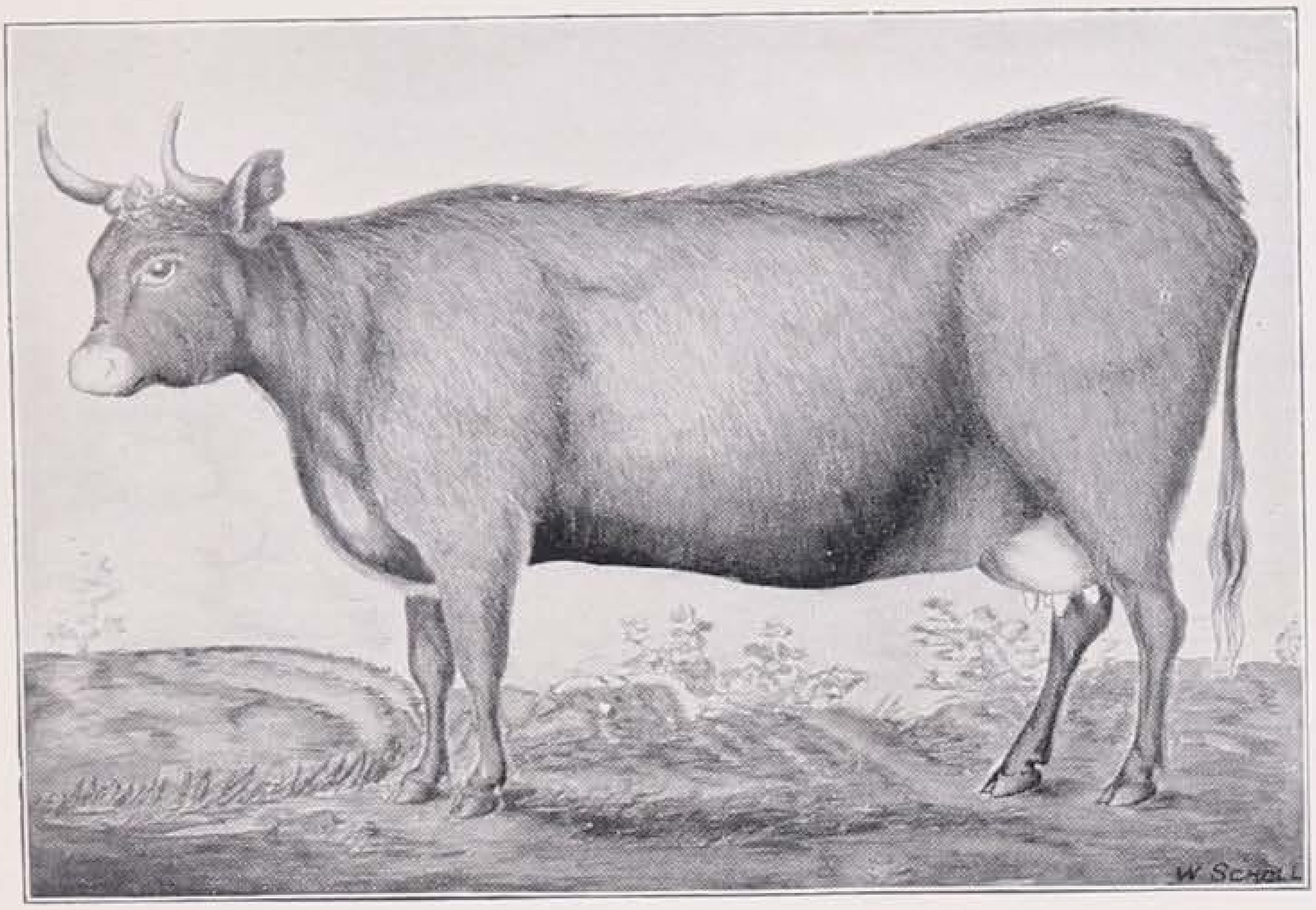


FIG. 1.—"THE OAKES COW."

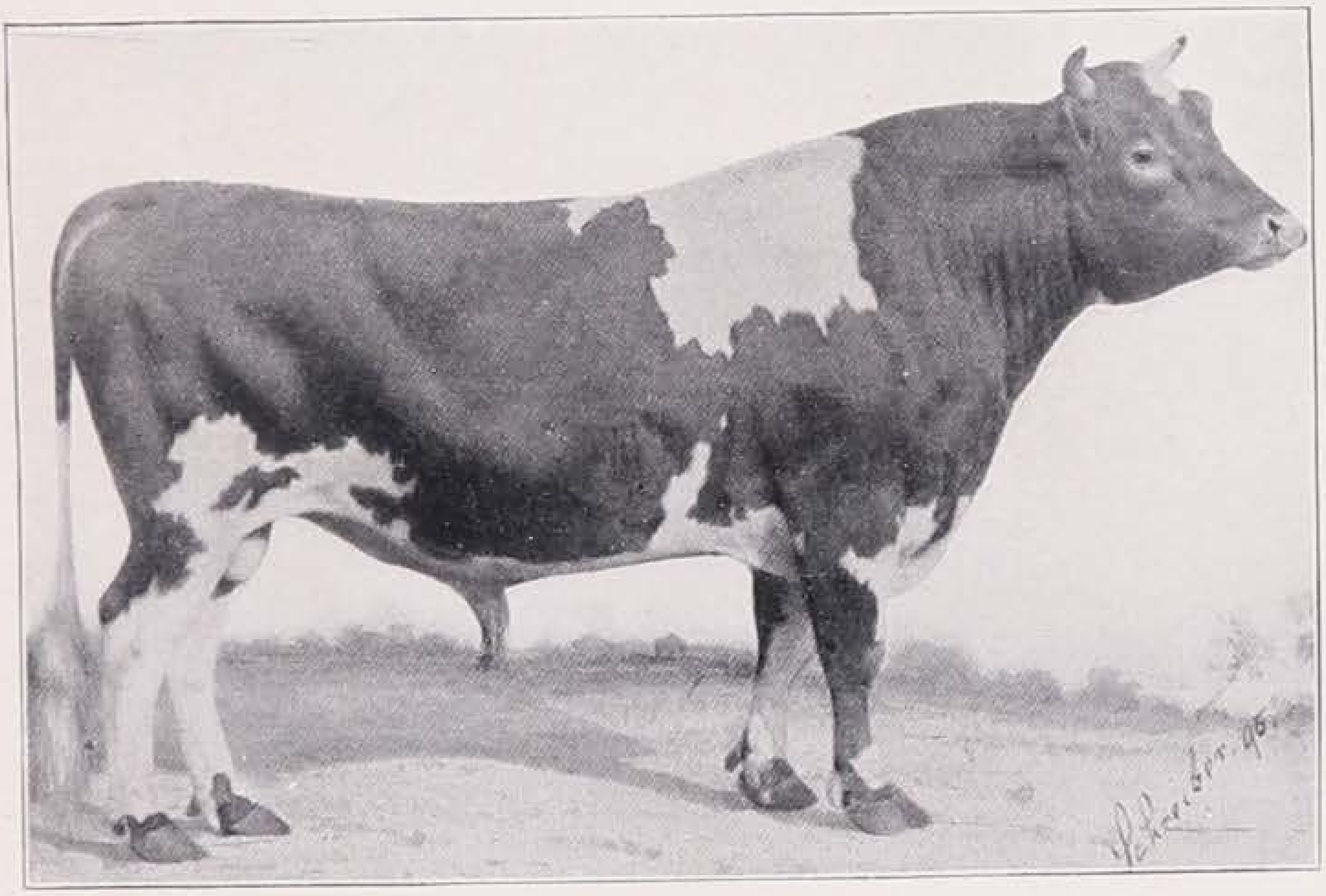


FIG. 2.—DAIRY BULL, MODERN TYPE. GUERNSEY.

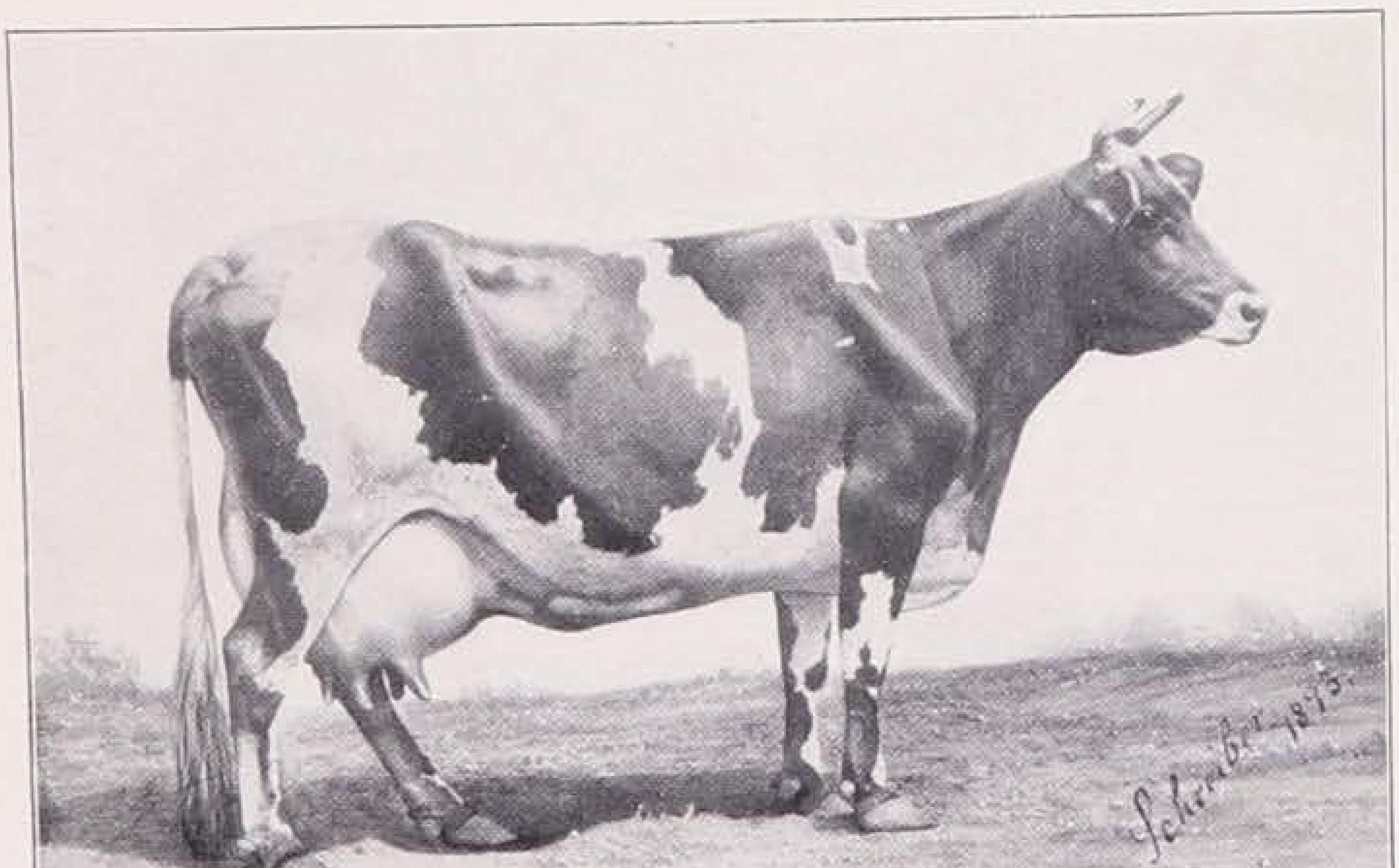


FIG. 3.—DAIRY COW, MODERN TYPE. JERSEY.

DAIRYING DURING THE CLOSING DECADES OF THE CENTURY.

The development of dairying in the United States during the closing decades of the nineteenth century has been uninterrupted and marked by events of the greatest consequence in its entire history. The importance of two inventions during this period can not be overestimated.

MECHANICAL SEPARATION OF CREAM FROM MILK.

The first is the application of centrifugal force to the separation of cream from milk. This is based upon the fact that the specific gravity of milk serum, or skim milk, is greater than that of the fatty portion, or cream. The dairy centrifuge, or cream separator (fig. 16), enables the creaming or "skimming" to be done immediately after milking, prefer-

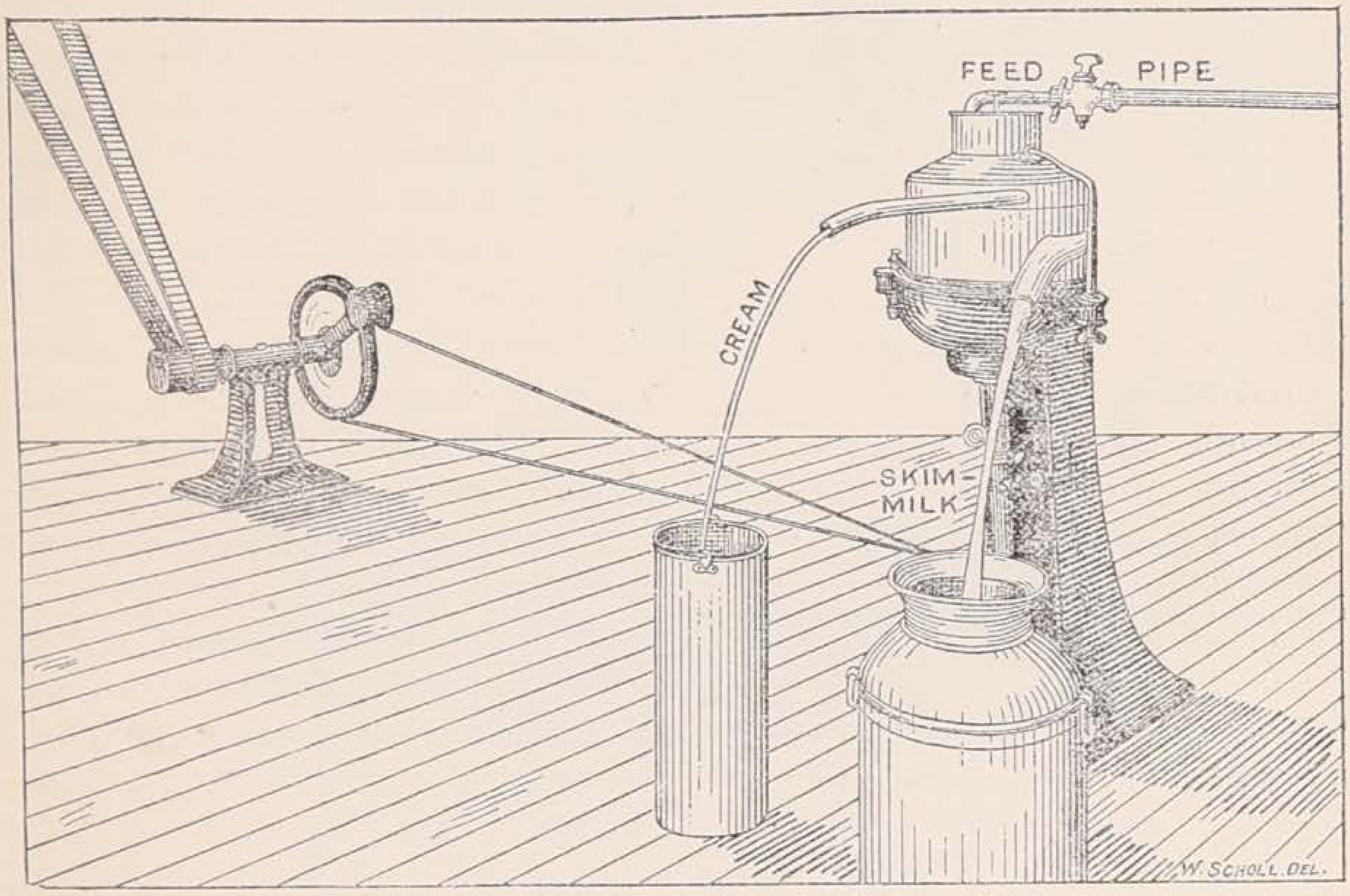


FIG. 16.—Centrifugal cream separator (in operation).

ably while the milk has its natural warmth. The cream can be churned at once, while sweet, but the better and usual practice is to cool thoroughly and then slowly cure, or "ripen," it for churning. The cream can be held at a comparatively high temperature, avoiding the necessity of much ice or cold water. The skim milk is available for use while still warm, quite sweet, and in its best condition for feeding to young animals. This mechanical method is more efficient than the old gravity system, securing more perfect separation and preventing loss of fat in the skim milk. It also largely reduces the dairy labor. The handling and care of the milk may be thus wholly removed from the duties of the household. Separators are made of sizes and patterns suited to farm use, and to be operated by hand or power—a dog or a sheep, a bull or a horse, water, electricity, or steam. The foregoing conditions apply when the separation is done on the farm where the milk is produced. In creamery practice the milk is usually aired and cooled on the patrons' farms and hauled once a day to the factory; there it is warmed to facilitate the work, passed through the separator, and the skim milk may be at once hauled back to the farms. A creamery uses one or more separators of large capacity, operated by power. This practice involves the double haul and an apparent waste of the farmer's time and labor. A movement toward economy in this respect is the establishment of "skimming stations" at convenient points, equipped with one or more power separators; to these the milk is taken for separation from the farms in the vicinity, and from these stations the cream is carried to the central factory for curing and churning.

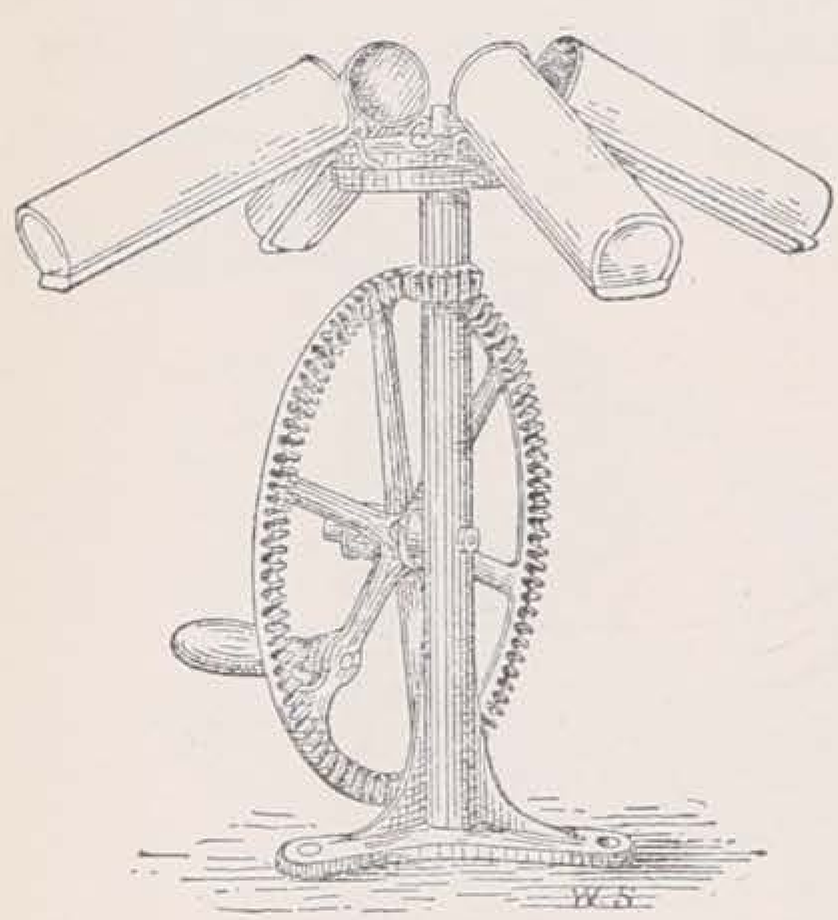


FIG. 17.—Babcock tester (cheap form, without bottles).

Besides its economy and its effect upon labor, the mechanical cream separator almost eliminates the factor of climate in a large part of dairy management, and altogether has worked a revolution in the industry. The centrifuge is still a marvel to those who see it working for the first time. The whole milk, naturally warm or warmed artificially, flows into a strong steel bowl held in an iron frame; the bowl revolves at rates varying from 1,500 to 25,000 times per minute, and from two projecting tubes the cream and skim milk separately flow in continuous streams. The machines can be regulated to produce cream of any desired quality or thickness. These separators of different sizes are capable of thus skimming or separating (more properly, creaming) from 15 to 500 gallons of milk per hour. A machine of standard factory size has a speed of 6,000 to 7,000 revolutions a minute and a capacity for creaming 250 gallons of milk an hour.

The world is indebted to Europe for this invention, at least as a dairy appliance. It is the only instance in which dairy invention abroad has been notably in advance of the United States. Yet, investigations were in progress contemporaneously in this country along the same line, and many of the material improvements in the cream separator and several novel patterns have since been invented here. The machine has been vastly improved during its twenty years of existence. At first the bowl was filled with a "charge" of milk, the separation effected, the machine stopped, its compartments emptied of milk and cream, then refilled and started again. The continuously acting machine was soon invented, however, and is now universal.

Most of the power machines are still operated by pulley, belting, and intermediate (as shown in fig. 16), but in the latest patterns steam is applied directly to a turbine wheel in the base of the standard. The first centrifugal separators were put into practical use in this country and Great Britain in the year 1879. On the continent of Europe they were used a little earlier. The century closes with more than 40,000 of these machines in operation in the United States.

FAT TEST FOR MILK.

The second great dairy invention of the period is the popular fat test for milk, being a quick and easy substitute for chemical analysis. This is one of the public benefactions of the agricultural experiment stations. In several States these stations have done much creditable

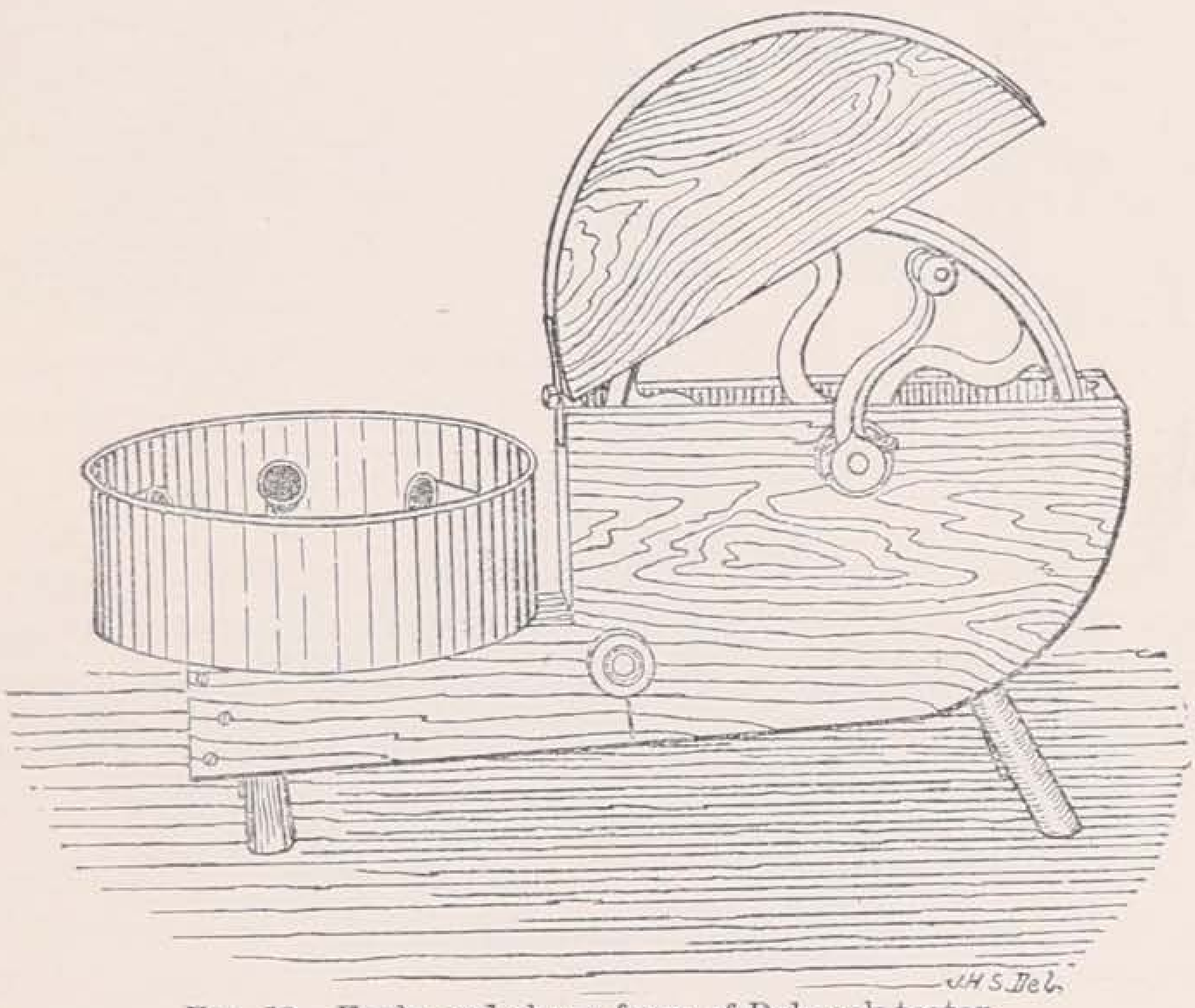


FIG. 18.—Early and cheap form of Babcock tester.

work in dairy investigation, and from them have come several clever methods for testing the fat content of milk. The one which has been generally approved and adopted in this and other lands is named for its originator, Dr. S. M. Babcock, chemist and dairy investigator, first of the New York experiment station at Geneva and since of the Wisconsin experiment station. (See figs. 17 to 21.) This test combines the principle of centrifugal force with simple chemical action. The machine on the Babcock plan has been made in a great variety of patterns, simple and inexpensive for home use and more elaborate and substantial for factories. By these machines from two to forty samples may be tested at once in a few moments, and by the use of bottles specially provided the percentage of fat may be determined in samples of milk, cream, skim milk, or buttermilk. Of course, the glassware appurtenances of these testers must be mathematically accurate. Besides the machine and its fittings, the only supplies needed are sulphuric acid of standard strength and warm water. Any person of intelligence can soon learn to make ordinary tests with this appliance, but care and skill are necessary to absolutely correct results.

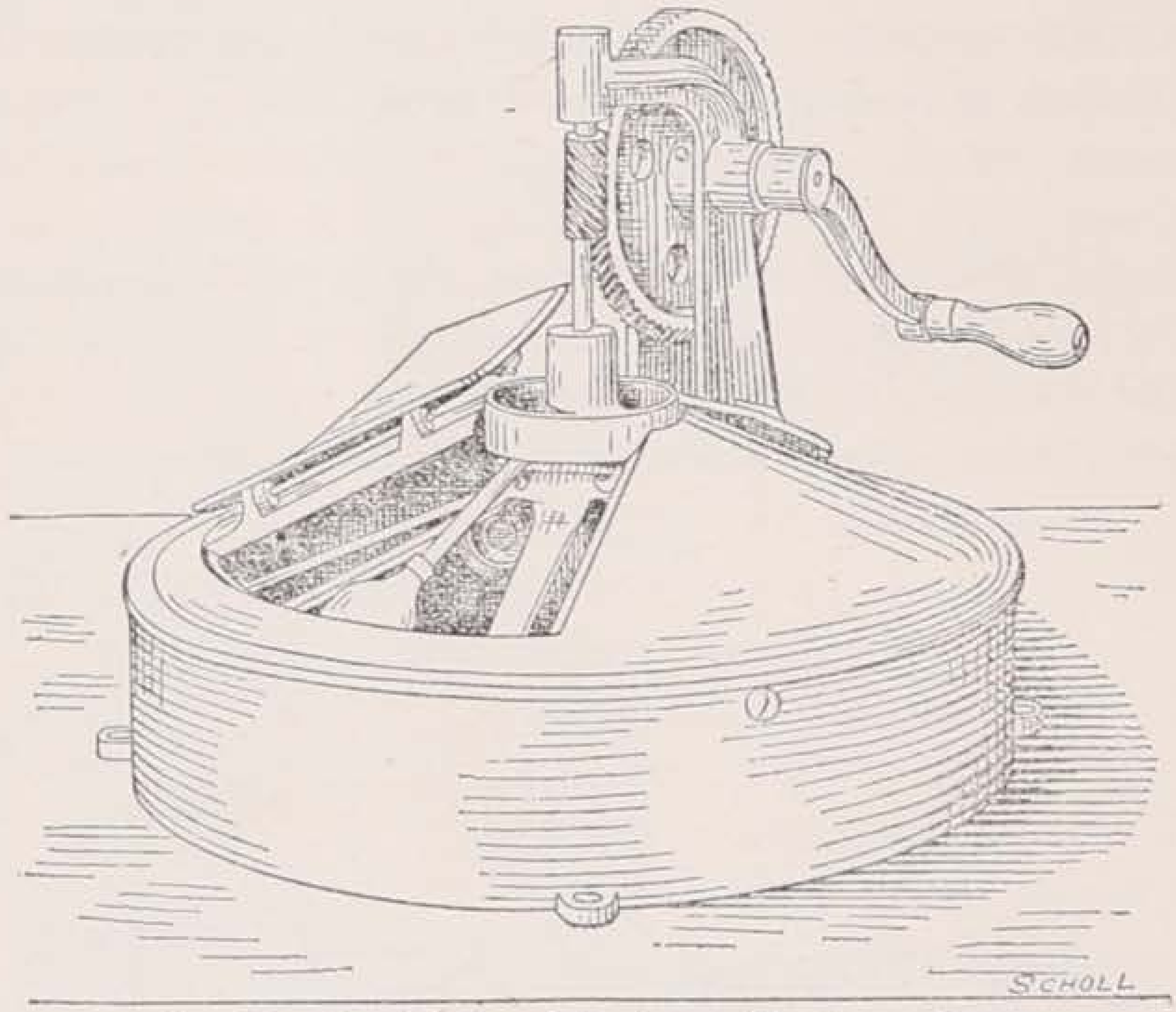


FIG. 19.—Hand Babcock tester, with strong drum.

This fat test of milk has wide application, and it may fairly be questioned whether it is second to the cream separator in advancing the economics of dairying. The percentage of fat being accepted as the measure of value for milk for nearly all purposes, the Babcock

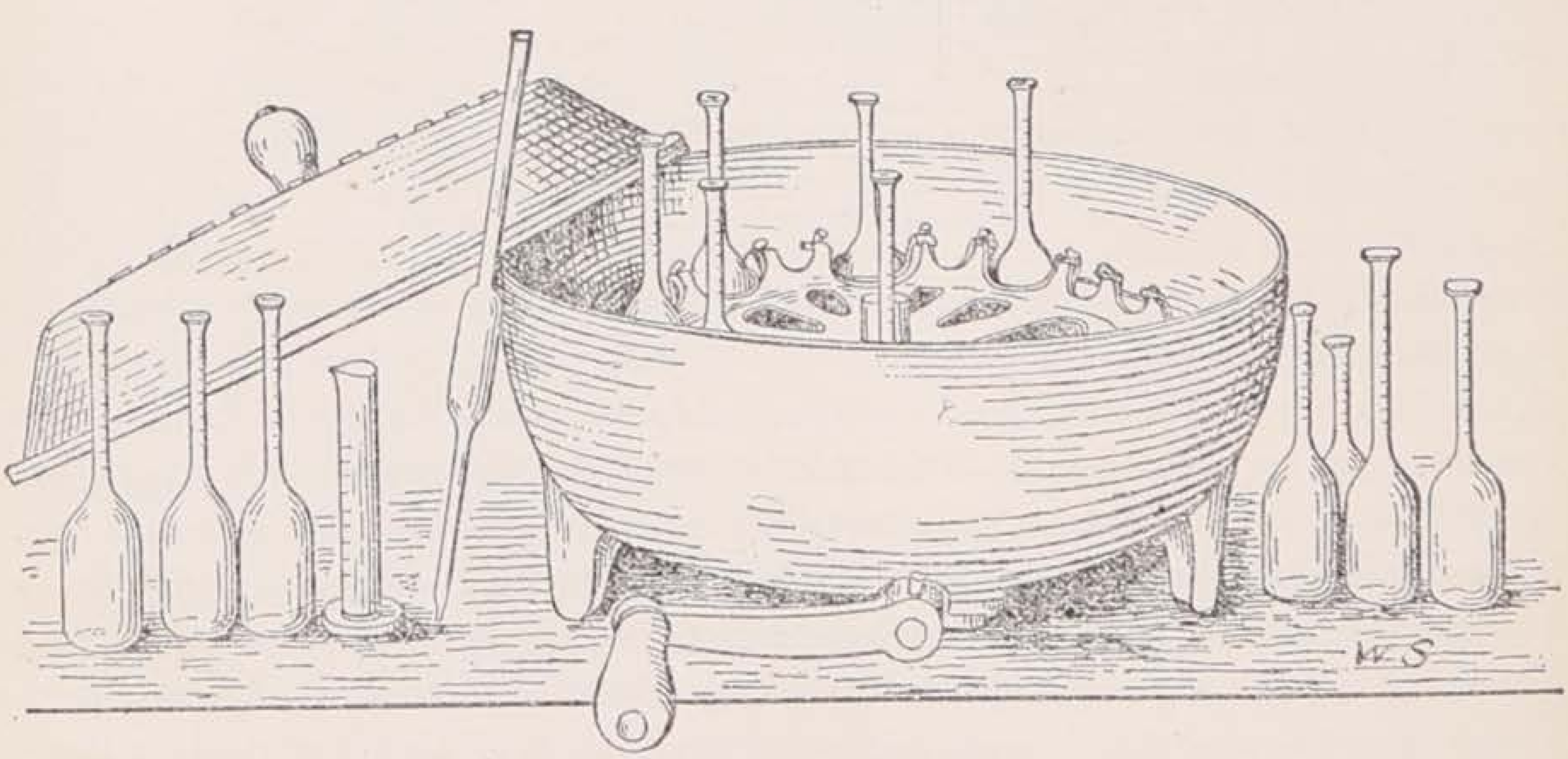


FIG. 20.—Hand Babcock tester, with variety of glassware.

test may be the basis for municipal milk inspection, for fixing the price of milk delivered to city dealers, to cheese factories, creameries, and condenseries, and for commercial settlements between patrons in cooperative dairying of any kind. By this test also the dairy farmer may prove the quality of milk from his different cows and (with quantity of milk yield recorded) may fix their respective value as dairy animals. Cows are now frequently bought and sold upon the basis of the milk scale and the Babcock test. With perfect apparatus in competent hands the accuracy of the test is beyond question, and it is of the highest scientific value and practical use. It should be noted that although clearly patentable, thus offering to the patentee an independent income through a very small royalty, this priceless invention and boon to dairying was freely given to the public by Dr. Babcock. Recognition of this public service has taken the form of a medal voted by the legislature of Wisconsin, and a handsome testimonial has been sent by the spontaneous action of appreciative creamerymen in distant New Zealand.

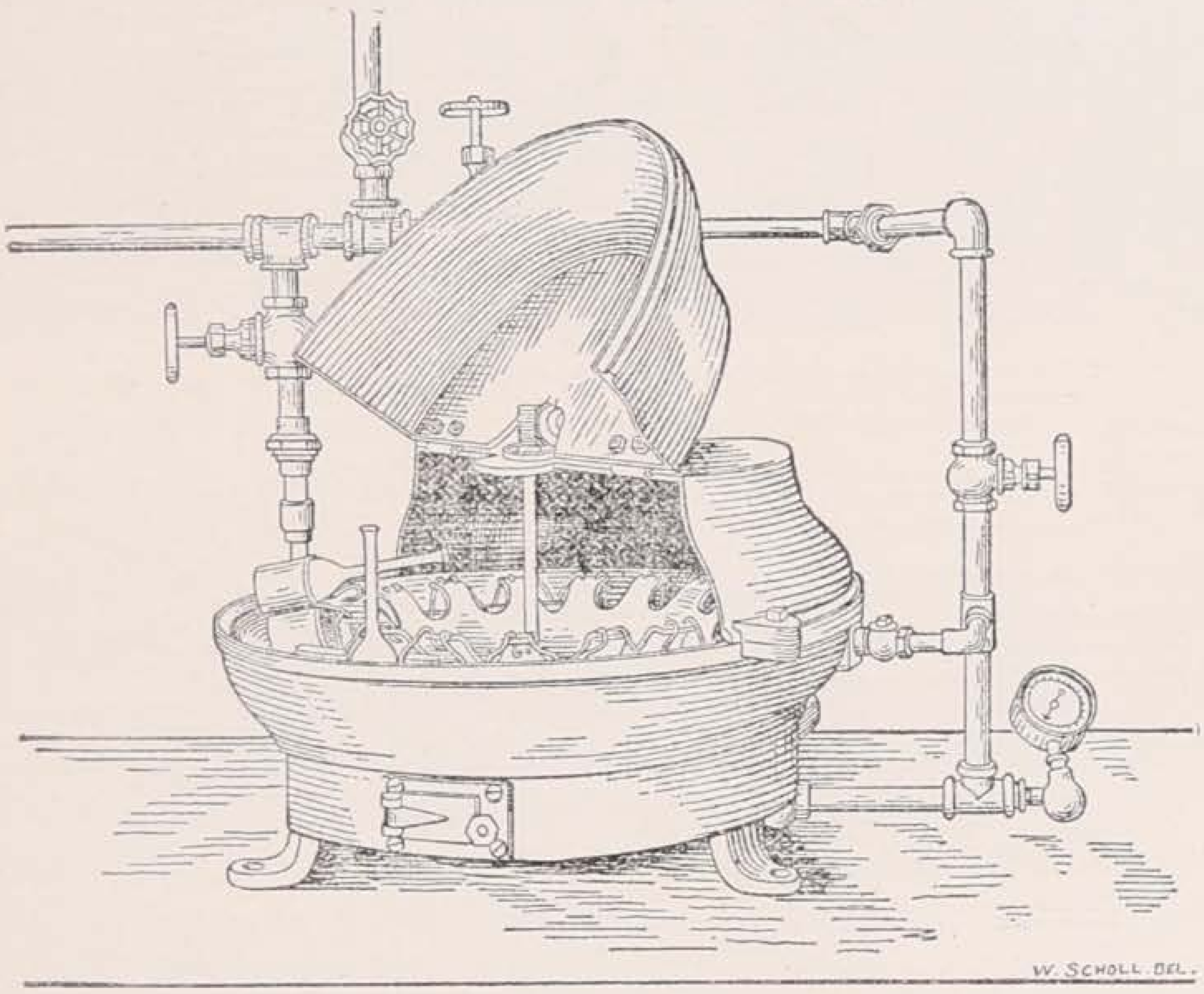


FIG. 21.—Babcock tester for use by direct steam power, or "turbine tester."

DAIRYING AT THE PRESENT TIME.

The advent of the twentieth century will find the dairy industry of the United States established upon a plane far above the crude and variable domestic art of three or four generations ago. The milch cow itself, upon which the whole business rests, is almost as much a machine as a natural product, and, as already shown, a very different creature from the average animal of the olden time. Instead of a few homely and inconvenient implements for use in the laborious duties of the dairy, perfected appliances, skillfully devised to accomplish their object and lighten labor, are provided all along the way. Long rows of shining tin pans no longer adorn rural dooryards. The factory system of cooperative or concentrated manufacture has so far taken the place of home dairying that in entire States the cheese vat or press is as rare as the handloom, and in many counties it is as hard to find a farm churn as a spinning wheel.

A SAMPLE OF THE CHANGES IN DAIRY PRACTICES.

Here is an example of the radical change wrought in dairy practices: Northern Vermont has long been a region of large butter production. St. Albans is the business center of Franklin County. During the middle of the century the country-made butter from miles around came to this market every Tuesday. The average weekly supply was 30 to 40 tons. This butter was very varied in quality, was sampled and classified with much labor and expense, placed in three grades, and forwarded to the Boston market, 200 miles distant. During twenty-five years ending in 1875, some 65,000,000 pounds, valued at $20,000,000, passed through this little town. All of this was dairy butter made upon one or two thousand different farms, in as many churns. In 1880 the first creamery was built in this county; ten years later there were fifteen. Now, a creamery company located at St. Albans has fifty-odd skimming or separating stations distributed through this and adjoining counties. (Pl. XX.) To those is carried the milk from more than 30,000 cows. Farmers having home separators may deliver cream which, being inspected and tested, is accepted and credited at its actual butter value, just as other raw material is sold to mills and factories. The separated cream is conveyed by rail and wagon—largely the former—to the central factory. There, in one room, from 10 to 12 tons of butter are made every working-day. A single churning place for a whole county! All of this butter is of standard quality, "extra creamery," and is sold on its reputation, upon orders from different points received in advance of its manufacture. The price is relatively higher than the average for the product of the same farms fifty years ago. This is mainly because of better average quality and greater uniformity—two important advantages of the creamery system.

METHOD OF MILKING UNCHANGED.

In one respect dairy labor is the same as a hundred years ago. Cows still have to be milked by hand. Although numerous attempts have been made, and patent after patent has been issued, no mechanical contrivance has yet been a practical success as a substitute for the human hand in milking. Therefore, twice a day, every day in the year, the dairy cows must be milked by manual labor. This is one of the main items of labor in dairying, as well as a most delicate and important duty. Allowing 10 cows per hour to a milker, which means lively work, it requires the continuous service of an army of 300,000 men, working ten or twelve hours a day throughout the year, to milk the cows kept in the United States.

FIG. 1.—SKIMMING STATION OF A VERMONT CREAMERY.

FIG. 2.—FRANKLIN COUNTY CREAMERY, ST. ALBANS, VT.

FIG. 1.—EXHIBIT OF FOREIGN BUTTERS BY THE UNITED STATES DEPARTMENT OF AGRICULTURE, 1899.

FIG. 2.—NATIONAL CREAMERY BUTTER MAKERS' ANNUAL COMPETITION, SIOUX FALLS, S. DAK., JANUARY, 1899.

FIG. 1.—IOWA DAIRY SCHOOL AND COLLEGE CREAMERY AT AMES.

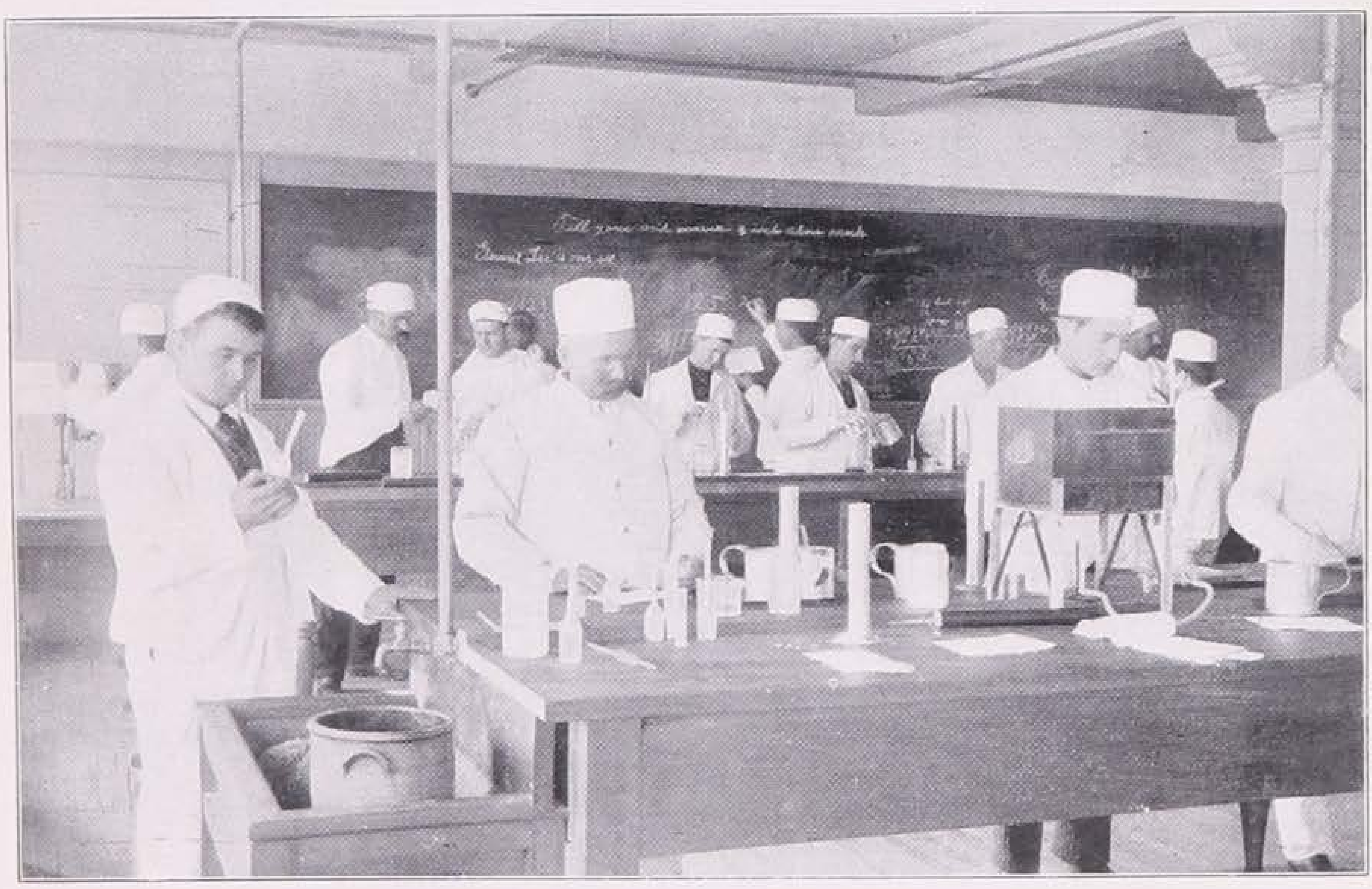


FIG. 2.—WISCONSIN DAIRY SCHOOL AT MADISON—MILK TESTING.

ORGANIZATION OF THE DAIRY INDUSTRY.

The industry is becoming thoroughly organized. Besides local clubs, societies, and unions, there are dairy associations in thirty States, most of them incorporated, and receiving financial aid under State laws. The proceedings of the annual conventions are, in several instances, reported and published at public expense. In some States the butter makers and cheese makers are separately organized; in some States creamery men and dairy farmers hold separate meetings. Large competitive exhibits of dairy products are also held, and Pl. XXI shows the annual exhibit for 1899 of the National Creamery Butter Makers at Sioux Falls, S. Dak., including the exhibit of foreign butters by the Department of Agriculture. Eighteen States provide by law for officials known as dairy commissioners or food and dairy commissioners. These officers have a national association, and there are also two national organizations of dairymen. At several large cities and centers of activity in the commerce of the dairy there are special boards of trade. The Department of Agriculture has a Dairy Division, whose purpose is to keep informed upon and to promote the dairy interests of the country at large. Dairy schools are maintained in a number of States, offering special courses of practical and scientific instruction in all branches of the business. (Pl. XXII.) These schools and the agricultural experiment stations, with which most of the dairy schools are connected, are doing much original research, and constantly adding to the store of useful information as to the application of modern science to this industry. Graduates from the schools are scattered all over the country as managers of dairy farms and superintendents of creameries and cheese factories, and are contributing to the general improvement in dairy methods and results. Weekly and monthly journals in the interest of dairy production and trade are published in various parts of the country, and during the last decade or two a number of noteworthy books on different aspects of dairying have been published, so that the student of this subject may fill a good-sized case with substantial volumes, technical and practical in character.

MILK PRODUCTION.

The business of producing milk for town and city supply, with the accompanying agencies for transportation and distribution, has grown to immense proportions. In many places the milk trade is regulated and supervised by excellent municipal ordinances, which have done much to prevent adulteration and improve the average quality of the supply. Full as much, however, is being done by private enterprise, through large milk companies, well organized and equipped, and establishments which make a specialty of serving milk and cream of fixed quality and exceptional purity. These efforts to furnish "certified" and "guaranteed" milk and general competition for the best class of trade are doing more to raise the standard of quality and improve the service than all the legal measures. The buildings and equipment of some of these modern dairies are quite beyond precedent. This branch of dairying is advancing fast, and upon the substantial basis of care, cleanliness, and better sanitary conditions. (Pls. XXIII and XXIV.)

CHEESE MAKING.

Cheese making has been transferred bodily from the realm of domestic arts to that of manufactures. Farm-made cheeses are hard to find anywhere; they are used only locally, and make no impression upon the markets. In the middle of the century about 100,000,000 pounds of cheese was made yearly in the United States, and all of it in farm dairies. At the close of the century the annual production of the country will be about 300,000,000 pounds, and 96 or 97 per cent of this will be made in factories. Of these establishments, there are nearly 3,000, but they vary greatly in capacity, and many are very small. New York and Wisconsin each has a thousand. The former State makes nearly twice as much cheese as the latter, and the two together produce three-fourths of the entire output of the country. The other cheese-making States, in the order of quantity produced, are Ohio, Illinois, Michigan, and Pennsylvania; but these are all comparatively unimportant. A change observed as taking place in the factory system is that of bringing a number of factories previously independent into a "combination" or under the same management. This tends to improve the quality and secure greater uniformity in the product, and often reduces cost of manufacture, all being decided advantages. More than nine-tenths of all cheese made is of the familiar standard variety, copied after the English Cheddar, but new kinds and imitations of foreign varieties are increasing. The cheese made in the country, with the small importations added, gives a yearly allowance of less than 4 pounds to every person; but as 30,000,000 to 50,000,000 pounds are still annually exported, the per capita consumption of cheese in the United States does not exceed 3½ pounds per annum. This is a very low rate, much less than in most European countries.

BUTTER MAKING.

Great as the growth of the associated system of butter making has been and fast as creameries have multiplied, especially in the newer and growing agricultural States, such as Minnesota, Nebraska, Kansas, South Dakota, and Washington, there is still much more butter made on farms in the United States than in creameries. Creamery butter controls all the large markets, the dairy products making comparatively little impression on the trade; but home consumption and the supply of small customers and local markets make an immense aggregate, being fully two-thirds of all. Estimating the annual

FIG. 1.—DAIRY BARN FOR 250 COWS IN NEW JERSEY.

FIG. 2.—MILKERS READY FOR WORK AT LARGE DAIRY FARM IN NEW JERSEY.

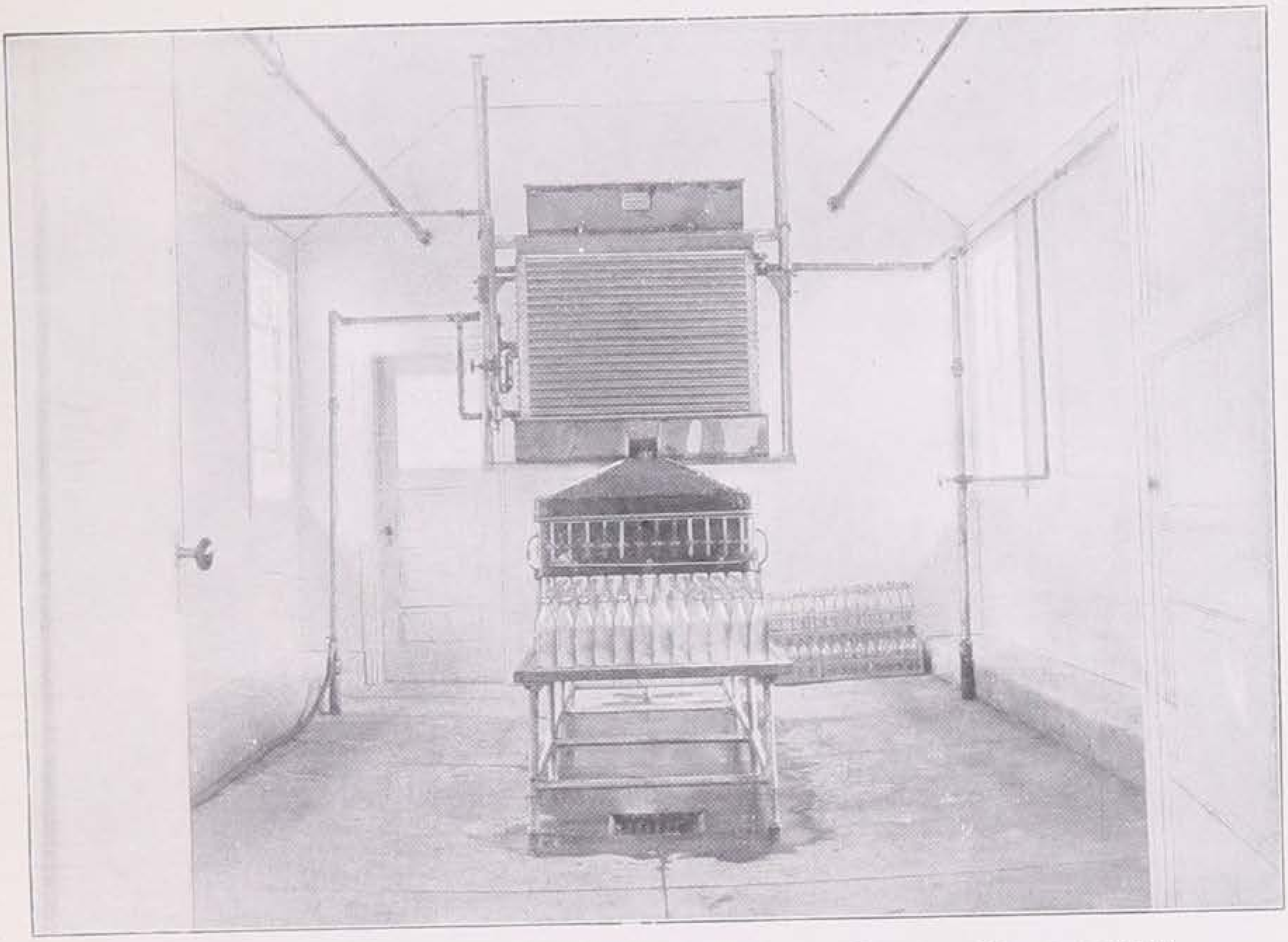


FIG. 1.—COOLING AND BOTTLING ROOM ON A DAIRY FARM IN PENNSYLVANIA.

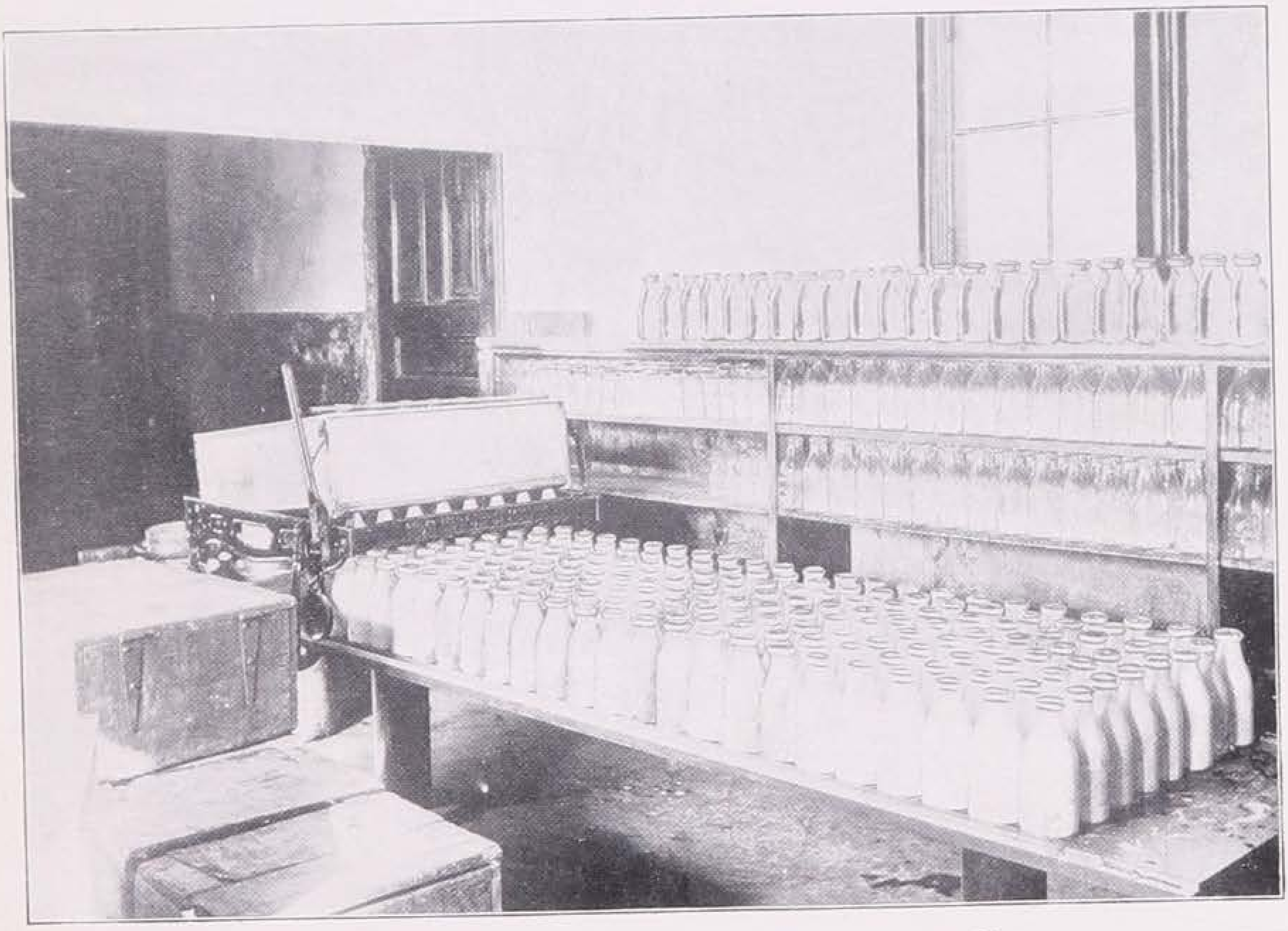


FIG. 2.—BOTTLING ROOM ON A DAIRY FARM IN NEW YORK.

butter product of the country at 1,400,000,000 pounds, not much over 400,000,000 of this is made in the 7,500 or 8,000 creameries now in operation. Iowa is the greatest butter-producing State and the one in which the greater proportion is made on the factory plan. This State has 780 creameries, only two counties being without them; about two-fifths are cooperative. In these creameries about 88,000,000 pounds of butter are yearly made from 624,000 cows. It is estimated that in the same State 50,000,000 pounds of butter in addition are made in farm dairies. The total butter product of this State is therefore one-tenth of all made in the Union. Iowa sends over 80,000,000 pounds of butter every year into other States. New York is next in importance as a butter-making State, and then come, in order, Pennsylvania, Illinois, Wisconsin, Minnesota, Ohio, and Kansas. Yet, all of these combined make but little more than one-half of the annual butter crop of the United States, and in no one of them except Iowa is half of the butter produced made in creameries. The average quality of butter in America has materially improved since the introduction of the creamery system and the use of modern appliances, and the average continues to improve. Nevertheless, a vast quantity of poor butter is made—enough to make a large and profitable business in collecting it at country stores at grease prices or a little better and rendering or renovating it by patent processes. This renovated butter has been fraudulently sold to a considerable extent as the true creamery article, of which it is a fair imitation while fresh, and several States have recently made laws to identify the product and prevent buyers from being deceived. No butter is imported into this country, and the quantity exported is as yet insignificant, although there is beginning to be a foreign demand for American butter. The home consumption must accordingly be at the yearly rate of 20 pounds to the person, or about 100 pounds annually to the family of average size. If approximately correct, this shows Americans to be the greatest butter-eating people in the world.

The people of this country also consume millions of pounds every year of butter substitutes and imitations, such as oleomargarine and butterine. Most of this is believed to be butter by those who use it, and the State dairy commissioners mentioned are largely occupied in the execution of laws intended to protect consumers from these butter frauds.

BY-PRODUCTS OF DAIRYING.

Within recent years there has been great development in the economical uses of the by-products of dairying. Ten years ago there were enormous quantities of skim milk and buttermilk from the creameries and of whey from cheese factories, which were absolutely wasted. At farm dairies these by-products are generally used to advantage in feeding animals, but at the factories, especially at the seasons of greatest milk supply, this most desirable method of utilization is largely impracticable. In many places new branches have lately been added to the industry, which make sugar of milk and some other commercial products from whey, and utilize skim milk in various ways. The albumen of the latter is extracted for use with food products and in the arts. The casein is desiccated and prepared as a baking supply and substitute for eggs, as the basis of an enamel paint, as a substitute for glue in paper sizing, and it is also solidified so as to make excellent buttons, combs, brush backs, handles, electrical insulators, and similar articles.

NUMBER OF COWS AND QUANTITY AND VALUE OF DAIRY PRODUCTS.

The cows in the United States were not counted until 1840, but have been since enumerated for every decennial census. It has required from 23 to 27 cows to every 100 of the population to keep the country supplied with milk, butter, and cheese, and provide for the export of dairy products. The export trade has fluctuated much, but has never exceeded the produce of 500,000 cows. With the closing years of the century it is estimated that there is one milch cow in the United States for every four persons. This makes the total number of cows, about 17,500,000. They are unevenly distributed over the country, being largely concentrated in the great dairy States. Thus, Iowa leads with 1,500,000 cows, followed by New York with almost as many; then Illinois and Pennsylvania, with about 1,000,000 each. The States having over 500,000 each are Wisconsin, Ohio, Kansas, Missouri, Minnesota, Nebraska, and Indiana. Texas is credited with 700,000 cows, but very few of them are dairy animals. In the Middle and Eastern States the milk product goes very largely to the supply of the numerous large towns and cities. In the Central West and Northwest butter is the principal dairy product. The following table gives approximately an exhibit of the quantity and value of the dairy products of the United States in the year 1899:

Estimated number of cows and quantity and value of dairy products.

Cows.	Product.	Rate of product per cow.	Total product.	Rate of value.	Total value.
				Cents.	
11,000,000	Butter	130 pounds	1,430,000,000 pounds	18	$257,400,000
1,000,000	Cheese	300 pounds	300,000,000 pounds	9	27,000,000
5,500,000	Milk	380 gallons	2,090,000,000 gallons	8	167,200,000

This gives the grand total of the dairy products of the country a value of $451,600,000. If to this be added the skim milk, buttermilk, and whey, at their proper feeding value, and the calves dropped yearly, the annual aggregate value of the produce of the dairy cows exceeds $500,000,000. Accepting these estimates as conservative, they show that the commercial importance of the dairying of the United States is such as to command attention and justify all reasonable provisions for guarding its interests.

DEVELOPMENT OF THE NUTRITION INVESTIGATIONS OF THE DEPARTMENT OF AGRICULTURE.

By A. C. True, Ph. D., *Director*, and R. D. Milner, Ph. B., *Assistant in Nutrition Investigations, Office of Experiment Stations.*

INTRODUCTION.

The subject of food economy in all its details, always of vital interest, has acquired increased importance in this country in recent years from the extensive investigations that have been made and are still being prosecuted in connection with and as a part of the work of the Department of Agriculture and the agricultural experiment stations. There had been a considerable amount of investigation of the food of man, as well as studies of the food of domestic animals, before the stations were established. Much of the early experimenting was carried on in connection with physiological investigations or other work connected with the study of medicine. Some of the investigations, however, are directly comparable with more recent work.

The first American investigation on the subject of human nutrition which has been found by the authors was prosecuted by J. R. Young in Philadelphia in 1803. It was entitled "Experimental inquiry into the principles of nutrition and the digestive process." The author studied the nutritive value and digestibility of such materials as sugar, gum, beans, and wheat, making experiments with frogs and other small animals. The article summarizes the ideas on human nutrition held at that time.

With the rise of the experiment stations inquiries into the composition of feeding stuffs and their appropriate use in the nutrition of domestic animals were undertaken, and have since been carried on quite actively. Later some of the stations undertook similar investigations of the food and nutrition of man. The science of the nutrition of man has so much in common with that of nutrition of animals that a distinction between the two is not easily made, and naturally they have been studied together. These researches have been carried on mainly in the physiological and chemical laboratories of universities as well as of experiment stations. On the whole, for the study of foods and the laws of nutrition, much more experimental inquiry has been made with animals than with men, partly because of the greater ease and convenience of experimenting with animals and partly because of the especial activity of the experiment stations in this direction. The attention devoted to the special study of feeding stuffs for animals, up to the present time, is likewise greater than that devoted to the special study of the food of man, leaving out of account, of course, the subject of food adulteration, which comprises a phase of the general investigations not discussed here.

The growth and development of this subject in the United States has an interesting history. Beginnings were made by physicians and other scientific investigators. Much of the work with which the nutrition investigations of this Department are directly connected and out of which they grew was of this nature, and not a little was made possible only by the generosity of private individuals; then economic institutions and Government scientific departments became interested, and finally the results of the work proved so valuable and useful that Congress made special appropriation for carrying on investigations in nutrition in different places throughout the country.

SCOPE OF INVESTIGATIONS ON THE FOOD AND NUTRITION OF MAN.

Investigations on the food and nutrition of man include the study of two branches of the subject, which, though quite intimately related and both valuable, are nevertheless of importance in different ways. One branch of the subject comprises a study of the chemical composition of different food materials, an investigation that is purely analytical, but a necessary preliminary to the investigation in the other branch of the subject, which comprises researches into the laws of nutrition and the economic and sociological application of the subject. The former has to do with simply the chemistry of food, while the latter has to do with the physiology—the physics and chemistry—of the nutrition of man, together with its economic and sociological application to people of different classes in different places and under different conditions.

From the first many investigations have been made which studied food incidentally in connection with some special problem—for instance, the effect of some drug. Mention should be made in this connection of the experiments of Professor Chittenden, of Yale University, on this and similar lines. This work is still carried on; the earliest results were published, however, some twenty years ago.

Some very interesting experiments have been made by earlier American investigators on the effect of muscular exertion on the production of urea. One of the most noteworthy investigations of this nature was made by Dr. Flint in 1871 with the professional pedestrian Weston. The earliest study of dietaries which the authors have found was made by J. S. Gould, published in 1852, entitled "Report on the food and diet suited for almshouses, prisons, and hospitals." These are only a few of the investigations which might be cited.

A considerable part of the early work in the study of foods in this country was analytical, along the line of the chemical composition of different food materials. A not inconsiderable amount of such work was done between the years 1840 and 1860, most of which, however, is of interest to-day chiefly from a historical standpoint. The greatest accuracy of the work done at that time was in the determination of the elementary composition and the inorganic compounds of the food products. A considerable number of analyses were carefully made in an attempt to learn the proximate composition also; but accurate and reliable methods of organic and analytical chemistry had not yet been fully developed, so the results are comparable only in a general way with those of analyses which have been made according to the so-called "Weende" methods, which were devised and came into general use about 1864. Since that time it has been possible to carry on systematic investigations of food materials from the standpoint of their nutritive values as determined by their chemical composition.

A considerable amount of investigation of materials used as food by man has been for many years and is still being carried on by the Division of Chemistry of the Department of Agriculture. Mr. Clifford Richardson made a large number of analyses of specimens of American flour and the bread made from them, and of fresh vegetables and other materials. Prof. H. W. Wiley, the present chief of the Division, and his associates, have also made a great many analyses of cereal grains and their products, canned foods, meats, and other materials. A great deal of study of the composition of food materials has been made by Professor Wiley in the prosecution of his investigations of adulteration of foods. A considerable number of analyses of foods, especially dairy products, sugars, fruits, and vegetables, were made elsewhere in this country prior to the establishment of the experiment stations. This work has been continued and materially extended by the stations.

INCEPTION OF THE PRESENT COOPERATIVE INQUIRIES ON THE NUTRITION OF MAN.

The particular inquiry on the nutrition of man, which has developed into the cooperative inquiries now being prosecuted in different parts of the country under the auspices of the Department of Agriculture, had its inception in the study of the chemical composition and nutritive economy of food fishes and invertebrates that was undertaken by Prof. W. O. Atwater in 1877, in the chemical laboratory of Wesleyan University, at the instance of Prof. S. F. Baird, Secretary of the Smithsonian Institution and United States Commissioner of Fish and Fisheries.

The investigations, begun then and continued until 1882, included (1) chemical analyses of fishes and invertebrates; (2) experiments upon the digestibility of fish; and, (3) studies of the chemical constitution of the flesh of fish. In the course of these investigations there were studied some two hundred specimens of marine and fresh-water fishes and invertebrates commonly used for food in the United States. For the prosecution of this inquiry small sums were appropriated from time to time, through the agency of Professor Baird, to defray the expense for apparatus and labor of assistants. Several citizens of Middletown, Conn., of New York, and of other places, feeling personally interested in and recognizing the need of just such work, contributed generously toward carrying out investigations much more elaborate and extensive than would have been possible without such material assistance. Doubtless from the interest of those individuals, manifested in such a manner, the work was given at once an importance which otherwise it might have been long in acquiring. The information regarding the food value of fish that was obtained through these studies emphasized the need of similar study of other food materials.

In 1884 Professor Atwater was asked to prepare plans for specimens, labels, and other illustrative materials for the food collection of the United States National Museum. In the development of these plans it appeared very desirable to illustrate the fundamental principles of food economy, for which purpose there was need of considerable information concerning the chemical composition of some of the more common food materials in use in this country. This information was not then available, because no extensive investigations of American food products had ever been made. To make such investigations was a large undertaking, and the necessity for doing so was not popularly understood. A beginning was made, however, with the hope that as the results of the work should appear and their value should be realized the means for continuing the inquiry would be found. By 1888 nearly one hundred specimens of food products, mostly animal, but including some vegetable, had been analyzed in the laboratory of Wesleyan University, the expense of the work being met in part by the National Museum and in part by contributions from private sources. In 1888 the Storrs experiment station was established and placed under the direction of Professor Atwater. Provision was made for conducting its chemical investigations in the Wesleyan University laboratory, and the analysis of animal and vegetable food products was continued as part of its work, both as independent inquiries and in connection with dietary studies and other investigations, which will be mentioned later.

The World's Columbian Exposition, in 1893, afforded a most favorable opportunity for collecting specimens of food materials of particular interest in the United States. On behalf of the executive committee on awards for that exposition, Prof. H. W. Wiley, of the Department of Agriculture, undertook the investigation and analysis of a large number of specimens of cereal grains and milling products from them, sugars, and other products. These investigations were carried on at the exposition and were completed later in the laboratory at Washington City. On behalf of the same committee, Professor Atwater undertook similar investigations of prepared foods, and especially animal foods. Over six hundred specimens of such foods were collected for this investigation. The work was carried on so far as possible at Chicago during the exposition. Afterwards it was transferred to Middletown, Conn., and was continued in the laboratory of Wesleyan University as part of the work of the Storrs station. Analyses of over five hundred specimens were completed by 1894. This was the most extensive investigation of this character undertaken up to that time in this country. In this work, as well as in other nutrition investigations, Prof. C. D. Woods has been prominently associated with Professor Atwater.

STUDY OF DIETARIES.

Meanwhile the investigations in nutrition had been begun along another line, namely, the study of dietaries, in an attempt to learn something concerning the character and quantity of food actually consumed by people in different circumstances of life in different localities. The first extensive work of this kind in this country carried on by the methods followed at the present time was undertaken by Hon. Carroll D. Wright, in 1886, while chief of the Massachusetts bureau of statistics of labor. For the purpose of supplying, in some measure, information necessary to enable the workingman to regulate more intelligently his expenditures for food and to secure with a given expenditure the maximum amount of nutritive ingredients, the bureau collected a number of schedules of dietaries, giving quantities and cost of food used by working people in different cities in Massachusetts and also in some localities in Canada, from which some of the working people had come. The data thus collected were submitted to Professor Atwater, under whose supervision the quantities of nutritive ingredients in the food purchased were estimated. The statistics of quantities of food purchased were compiled from original accounts with tradesmen. No analysis of foods was made in these studies. The amounts of ingredients contained in the food were estimated upon the basis of the results of analyses of similar foods already made. So far as possible, American analyses were used; for the materials of which no analyses had been made in this country, however, the results of European analyses were employed.

The results of these studies were only approximately correct. In order to secure more reliable data, which might be useful in estimating dietary standards and in more accurate inquiry in food economy, similar studies were carried on at Middletown, Conn., under the direction of Professor Atwater. In these studies the errors in collecting data observed in the preceding studies were eliminated so far as possible, and analyses of many of the foods used were actually made.

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The classes of people studied included not only laborers' families, but also students' boarding clubs and well-to-do persons. The results of these studies, together with those of the former studies, seemed to warrant generalizations of considerable interest, and particularly to indicate the directions in which further inquiry was needed. The work thus done represented the beginning of an investigation of an important subject. In 1890 the Storrs experiment station, in cooperation with the United States Department of Labor, which had been established with Hon. Carroll D. Wright as Commissioner, undertook a series of accurate dietary studies, which were continued for several years. By January, 1895, twenty-one such studies of the actual food consumption of families of mechanics and professional men had been made and reported by the station. Similar investigations have since been carried on elsewhere, especially under the auspices of the Department of Agriculture, as explained in a later paragraph, so that at the present time the results of about three hundred such studies are recorded, while the work is still going on.

STUDY OF THE DIGESTIBILITY OF DIFFERENT FOOD MATERIALS.

The value of different foods for nutriment depends not only upon the kinds and amounts of nutritive ingredients which they contain, as determined by chemical analysis, and upon the quantities in which they are used in the dietaries of different people, but it depends also upon the proportions of the different nutrients which can be digested from the foods by persons under normal conditions as to variety and amounts of food consumed, habits of living, and general health. For this reason one very important part of the investigations in food and nutrition of man has been the study of the digestibility of different food materials, with particular reference to the proportions of nutrients that may be digested from them. This study has been made by actual experiments with men in which the coefficients of digestibility of food materials were determined from the amounts of nutrients in the food eaten and in the feces excreted.

Previous to the spread of investigations in nutrition in this country very little research had been made along this line. Even in Europe, where the study of nutrition had been carried on for many years, the number of digestion experiments with men was not large. In connection with the nutrition investigations which are being carried out by the Department of Agriculture in cooperation with experiment stations and other institutions more than one hundred and fifty digestion experiments have already been made, and at the present time some series of elaborate experiments are still in progress.

STUDY OF THE FUNCTIONS OF FOOD IN THE BODY.

One important function of food is to furnish energy to the body. For a thorough study of the laws of nutrition, therefore, and of the uses and nutritive values of food, there must be a means of determining the amounts of energy potential in the food consumed and in the products formed from the food by the body. Since different forms of energy may be transformed into heat, the energy of a substance may be expressed in terms of heat, and therefore the potential energy of a substance may be measured by the heat developed when the substance is burned in oxygen. A method is employed whereby the amount of heat thus developed by food materials is determined. The result obtained in this way is called the "heat of combustion" of the material burned. The apparatus used for this purpose is called a calorimeter, various forms of which have been devised. The early work done by the Storrs station along this line was by use of a Stohmann calorimeter, a modification of that of Thompson. This apparatus proved unsatisfactory, and the attempt was made to secure a better one. The bomb calorimeter devised by Berthelot was superior, but was very costly, because of the large amount of platinum used in its construction. With the aid of Professor Hempel, of Dresden, Professor Atwater and his associates succeeded in modifying the Berthelot apparatus, especially with regard to the amount of platinum used, so that a very accurate and satisfactory calorimeter has been obtained at a much lower cost. Mr. O. S. Blakeslee, mechanician of Wesleyan University, devised and elaborated considerable accessory apparatus, which has contributed largely to the success of the calorimeter. By the use of this apparatus the heats of combustion of a large number of different food materials have been determined.

In the study of nutrition of both man and domestic animals at the present time, considerable attention is paid to the fuel value of foods, that is, to their actual value to the body as sources of energy. This net value is taken as the heat of combustion of the total food consumed, minus the sum of the heats of combustion of the unoxidized material in the feces and in the urine. The values thus determined are used in the calculation of dietary standards, which serve to indicate in a general way the proportions of the nutritive ingredients of food that are appropriate for people in different conditions.

Studies of some of the more fundamental laws of animal nutrition have been carried on for the purpose of determining what uses the body makes of its food under different conditions. Special inquiries of this nature were begun by Professor Atwater and associates in 1892 by means of an apparatus known as a respiration calorimeter, so arranged that a man may spend a number of days in comparative comfort within it, and so manipulated that the metabolism of both matter and energy in his body may be determined. In devising and perfecting the apparatus and in carrying out the investigations with relation to the measurements of heat and mechanical work, Professor Atwater was assisted by Dr. E. B. Rosa, professor of physics in Wesleyan University. Dr. F. G. Benedict, instructor in chemistry, and

Mr. O. S. Blakeslee were also important contributors to the development of the apparatus, and Dr. Benedict has had a very important part in the experiments made with it. Several years were spent in the development of this apparatus and the elaboration of methods of experimenting with it. By the winter of 1895-96 the apparatus was considered accurate enough to justify its use in experiments with men, and several experiments were made in which determinations of the metabolism of matter were made with considerable accuracy. The determinations of the metabolism of energy, however, were not considered sufficiently accurate. As experience in the use of the calorimeter was gained several improvements in the apparatus and in methods of manipulation were made, until the results finally obtained were as accurate as those secured in investigations on a much smaller scale, in which ordinary laboratory methods are followed. Later experiments are furnishing definite, accurate information concerning the action of the fundamental laws of the conservation of matter and of energy in the living organism. The results already attained show remarkable agreement in income and outgo of both matter and energy in the bodies of men at work and at rest, with different kinds and amounts of food, thus giving very exact indication of the ways in which food performs its functions in the body. These results are exceedingly valuable from the standpoint of both pure science and practical utility.

NUTRITION INVESTIGATIONS UNDER THE DEPARTMENT OF AGRICULTURE.

The greater part of the investigations in the food and nutrition of man above referred to as carried on previous to 1894 were made by the aid of contributions from private individuals,[1] though funds were supplied by the Storrs experiment station, and more especially by the Smithsonian Institution and the United States Fish Commission, through Prof. S. F. Baird, and by the United States Department of Labor, through Commissioner Carroll D. Wright.

As early as 1890 the results of the nutrition investigations already made had aroused so much public interest that steps were taken to induce Congress to appropriate funds for carrying on the work. Nothing definite was accomplished there, however, until 1894. In that year the act of Congress providing appropriations for the experiment stations and authorizing the inquiries which they were to conduct was changed so as to include the study of the food of man. The experiment stations were called upon to report progress in the work to the Secretary of Agriculture. At the same time Congress provided a special appropriation of $10,000 "to enable the Secretary of Agriculture

[1] Among the contributors may be mentioned Hon. J. W. Alsop, M. D., I. E. Palmer, and A. R. Crittenden, of Middletown, Conn., and Messrs. F. B. Thurber and E. G. Blackford, of New York.

to investigate and report upon the nutritive value of the various articles and commodities used for human food." The prosecution of this inquiry was assigned to the Office of Experiment Stations, and Professor Atwater was appointed special agent in charge of the nutrition investigations. In the following year the appropriation was increased to $15,000, which amount has been provided annually since then. The State of Connecticut, by act of legislature of 1895, also makes an annual appropriation of $1,800 to Storrs experiment station, the larger part of which is to be expended in the study of nutrition.

THE PRESENT COOPERATIVE NUTRITION INVESTIGATIONS.

The work in charge of the Office of Experiment Stations is carried out largely in cooperation with scientific and educational institutions and philanthropic organizations in different parts of the country. Extended series of investigations have been prosecuted in Maine, Connecticut, New York, New Jersey, Pennsylvania, Virginia, Tennessee, Alabama, Missouri, Indiana, Illinois, Minnesota, North Dakota, California, and New Mexico. The Department of Agriculture has cooperated in New York City with the Association for the Improvement of the Condition of the Poor and the Industrial Christian Alliance in studying the food and nutrition of the people of the congested districts. Similar work has been done with Hull House in Chicago. The Polytechnic Institute and the Tuskegee Institute in Alabama and the Hampton Institute in Virginia have made investigations in their regions, particularly among the negroes in the Black Belt of the South. In other localities experiment stations, colleges, and universities make investigations among people of various classes and conditions of life, including not only dietary studies but also other phases of the subject of the nutrition of man.

The method of cooperation adopted in the prosecution of these studies has some very decided advantages, particularly in the fact that so many different institutions, representing the varied interests of people in widely separate regions, unite in a study of prevalent conditions and an effort for improvement. Besides this, the funds provided from the Department of Agriculture are used economically and are often supplemented by means from other sources. By this extensive cooperation of individuals and institutions with the Department, under very favorable conditions, a large amount of valuable work is being done systematically, the results of which are made available to the public. In the judgment of competent experts, it is more thorough in its scientific methods, more extended in the scope and amount of investigation, and more useful in the distribution and practical application of its results than any other inquiry of the kind ever undertaken in this country or in Europe.

The more important topics that have thus far received special attention are the composition of food materials; the kinds and amounts of food consumed by individuals, families, boarding houses, and institutions; the digestibility of food materials, and the fundamental laws of nutrition. A variety of collateral questions have also received much attention. The results of these investigations are given in bulletins both of a popular and technical character, which are issued through the Office of Experiment Stations. The results of analyses of food materials made in the United States have been compiled and printed in a bulletin for popular use. In a revision of this bulletin, issued during the past year, the compilation was based upon over four thousand analyses, the larger portion of which were made in connection with the nutrition investigations. The results and discussion of dietary studies also appear in bulletins prepared for popular use. The results of digestion experiments and metabolism investigations with the calorimeter are given in bulletins which are more or less technical in character, intended rather for the scientific student of the subject.

FEATURES OF THE NUTRITION INVESTIGATIONS.

From the scientific standpoint, the most noteworthy feature of these inquiries is found in the researches with the Atwater-Rosa respiration calorimeter, by means of which the study of the application of the laws of conservation of matter and of energy in the human body are being carried out with a completeness not previously attained. Indications of the value of this apparatus and method of inquiry are apparent in the fact that an apparatus on the same general plan, but large enough for experiments with domestic animals, is already in process of construction at the experiment station of the State College of Pennsylvania, under the direction of Prof. H. P. Armsby, and in cooperation with the Bureau of Animal Industry of the Department of Agriculture. The Prussian Government has provided means for the construction of a similar apparatus for the Institute of Animal Physiology at Bonn, under Professor Hagemann. An appropriation under Government authorization has also been made for the construction of a like apparatus in connection with the Institute of Animal Physiology at Budapest, under Professor Tangl.

From the practical standpoint, the information gathered in the nutrition investigations is already being utilized, and the interest of economists, educators, and housekeepers in the results is constantly increasing. The results are being utilized in the determination of rations for the Army and Navy of the United States. Public institutions, in which dietaries are made up for a considerable number of persons, are likewise taking advantage of them. The New York State Commission in Lunacy, which has charge of all the public insane hospitals of that State, has employed Professor Atwater as a consulting expert on nutrition, and special studies of dietaries for these institutions are being conducted under his direction with a view to the improvement of the dietaries for the insane patients as regards both quality and economy. The usefulness of this work is by no means confined to the United States, but is extending to other countries as well.

INTEREST OF SCHOOLS AND OTHER INSTITUTIONS IN NUTRITION INVESTIGATIONS.

One especially encouraging feature is found in the interest in the subject that is being continually manifested by progressive educators. There is much reason to hope that gradually the results of these inquiries will find place in regular public school instruction, and thus become a part of the common knowledge of the community.

In the last report of the Bureau of Education it was stated that 146 cities in the country have introduced into the curricula of the public schools some form of manual training, many other cities contemplate it, and it will doubtless soon be a part of our school system. The form of this training at present offered to girls is in the main cooking, but there is a growing feeling among educators that it is the science of nutrition and plain facts about food in its relation to healthful living that should be taught.

Schools of domestic science and schools of cookery each year pay more attention to the scientific side of nutrition, and in a number of instances have undertaken investigations of considerable practical importance as well as scientific value.

A number of schools and colleges have taken up the study of dietaries with a view to improving the diet of their students or making it more rational. The same is true of charitable institutions, hospitals for the insane, prisons, and other institutions where a large number of people must be fed. In such institutions it is, of course, desirable to make the diet sufficient in amount and suited to the needs of the persons consuming it. It is obvious that a small saving per capita is a matter of considerable importance in the aggregate. In several instances a study of the kind and amount of food consumed has shown that such a saving was possible while at the same time the diet was materially improved.

An examination of the files of medical journals and scientific periodicals published in this country shows that the earlier volumes contained few articles on investigations of nutrition, the chemistry of food, and similar topics; whereas the total number of such articles published in similar journals within the last few years is quite large.

Requests for bulletins and information received by the Department of Agriculture from schools, clubs, and individuals show that the interest in nutrition investigations is not confined to any one region or to persons following any special line of work, but that it is general and widespread. Offers of cooperation in food investigations are frequently made by universities, schools, and individual workers, and it would be quite possible to extend the work and very materially increase the total output of American investigations on this line, provided more funds were available for the purpose.

REACTION OF DEPARTMENT OF AGRICULTURE NUTRITION INVESTIGATIONS UPON SCIENTIFIC RESEARCH.

The reaction of this inquiry upon scientific research and the scientific spirit in institutions where investigations are being carried on deserves special mention. It has been the policy of the Department of Agriculture to encourage inquiry by investigators and organizations, and in institutions whose own resources in the form of money and of labor can be devoted to the purpose, the funds supplied by the Department being regarded as supplementary. In this way the appropriation by Congress becomes to a considerable extent a fund for aid of scientific research. Two important advantages are evident in such a policy. On the one hand, the amount and value of the product, and consequently the direct benefit to the community, are very much larger than could otherwise be obtained from like expenditure of public funds. On the other hand, the aid thus given by the Government to research in different parts of the country is a very important stimulus, encouraging professors of institutions to undertake and trustees to support inquiries which without such aid would not be undertaken, and enabling gifted and aspiring students to enter fields of original inquiry such as will be useful to both themselves and the public as well as to the cause of science in general.

THE PRACTICE OF FORESTRY BY PRIVATE OWNERS.

By Henry S. Graves,

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INTRODUCTION.

The general movement in the United States in favor of conservative forestry began about twenty-five to thirty years ago. During this time, through the medium of newspapers and magazines, Government and State publications, and scientific and other associations, the importance of a strong federal and State forest policy has been emphasized, and private owners have been urged to adopt careful methods of handling their woodlands. Some of the results of this agitation are well known, such as the withdrawal from sale of about 47,000,000 acres of public land to be held as federal forest reservations, the establishment of State reservations in New York and Pennsylvania, the institution of a system of fire patrol in Maine, New York, New Hampshire, Minnesota, Wisconsin, and Pennsylvania, the appointment of forest commissioners or similar officers in Maine, New Hampshire, New York, Pennsylvania, Minnesota, Wisconsin, and Kansas, the organization of two forest schools in the East and two in the West, as well as the establishment of courses of lectures on forestry in many agricultural colleges, and the creation of a lively interest in the subject throughout the country. What effect the efforts of the advocates of forestry have had on the handling of private woodlands is, however, not known to the general public, many believing that, with the exception of a few conspicuous examples, real forestry has not been practiced at all. As a matter of fact, a large amount of work has been done along the lines of conservative forest management, although it has not been known under the name of forestry. It is nevertheless a fact that wherever land is managed with the intention that it shall yield repeated crops of timber, and is so treated that the producing power is maintained at a high point, there true forestry is practiced.

A large number of owners in nearly every State have carried on work which comes entirely within this definition of true forestry, but their holdings are for the most part comparatively small. The majority of the large owners, the lumber companies, have not cut their forests with reference to the future production of timber, except in some of the spruce sections of the Northeast. Throughout the far West, and in many parts of the East, the danger from fire is so great that most owners have not cared to leave money invested in the forest in the form of small growing trees which otherwise might be utilized with present profit. In other sections, notably the Lake States, the taxes are so high that many owners could not afford to hold the land for future crops of timber, even if there were no danger from fire. In such localities it has been the object of lumbermen to remove the timber as soon as possible, with no intention of ever cutting over the land a second time. This system of lumbering, together with the great destruction of the forests by fire, has given the impression that there is no careful forestry in this country at all, and the work of the many small owners and of the few large owners who have managed their lands conservatively has been overlooked. It is the purpose of this paper to review briefly the work already done by private owners along the lines of forestry, much of which, though lacking system and imperfect in methods and results, shows the intention of true forestry and marks a great advance in the treatment of our forests.

In order to come in touch with private owners who have carried on such forest work as has been described, the Division of Forestry issued a circular letter of inquiry regarding the prevailing methods of handling woodlands. Answers were received from about 2,000 persons from forty-six States and Territories, nearly 1,000 of whom stated that they had done some work which might be classed as forestry. The material was so voluminous that only a general account of the work can be given here, with special reference to the more instructive examples.

EARLY EFFORTS OF PRIVATE OWNERS.

The earliest attempt at conservative forestry of which the writer has record was made in Connecticut in 1730, when Jared Eliot, of Guilford, in connection with Governor Bulkley and a Mr. Livingston, of New York, started a small blast furnace at Old Salisbury. The wood used in making the charcoal needed in the furnace was cut from the neighboring woodlands, and instead of clearing the forests, as was usually done, a careful system of thinning was adopted. Only the large trees were cut, while the small specimens were left standing to shade the ground and to grow to a larger size. Tradition states that under this system the owners returned for successive crops every twenty years, and it is reported that timber is still being cut periodically from this same land. A similar system of careful cutting is said to have been used by a large number of farmers in New England early in this century, and the practice was without doubt inaugurated very soon after the country became thickly settled. Some farmers went further than simply to select with care the trees which they wished to use or sell, and made thinnings with the sole view to improve the remaining trees. Thus, it appears that in 1840 B. F. Cutter introduced on his land in Pelham, N. H., a system of improvement cuttings. It seems that an abandoned field had sprung up to white pine and gray birch, and that when the trees were about 20 years old the birches began to be broken by the wind and to die. Wishing to save the wood before it decayed, Mr. Cutter cut out all the birch, leaving the pines untouched for twelve years longer. He then saw that a considerable number of the latter were being crowded out and were dying from lack of growing space and light, and accordingly he thinned out all the weak and unlikely trees, leaving the strong, vigorous specimens for the final crop. His labor was repaid by the wood which he took out and the improvement of the remaining trees, which grew more rapidly on account of the increased amount of light and space.

The planting of forest trees on waste lands was begun in Massachusetts at a very early date. It is said that between 1740 and 1750 an experiment in planting trees for ship timber was made at Pembroke, Mass. Tradition relates that the plantation was a complete success, and that timber was cut from it about 1810. Another early plantation was made in Bristol County, Mass., in 1790, where a farmer stocked a field with young oaks by sowing it with acorns. One of the first experiments in planting of which there is record was made in 1819 at Chelmsford, Mass., where Rev. J. L. Russell transplanted a large number of pitch-pine seedlings from a field, which he wished to cultivate, to a stretch of barren drift sand. He was much laughed at by his neighbors, but to their astonishment the trees flourished, and in twenty years he had a fine grove of pines, 6 to 8 inches in diameter. Of still greater interest and value as an illustration is the plantation of Zachariah Allen, at Smithfield, R. I., who planted about 40 acres of waste land in 1820 with chestnut, oak, hickory, and locust. The seed was sown in plowed furrows on the smooth ground, and in rough places was dropped in holes made by a hoe or a similar implement. A careful account of all expenditures and receipts was kept, and at the end of fifty-seven years the books showed a profit of 6.92 per cent on the capital invested. Similar plantations were doubtless made in the early part of the century, but no definite record of them can be obtained.

Planting on a large scale was begun in eastern Massachusetts in the present century as early as the forties. The best known of the plantations are those of Richard Fay, at Lynn, who planted about 200 acres, in 1846–1850, with oak, ash, maple, Norway spruce, Scotch pine, and larch, and of Joseph S. Fay, at Woods Hole, who a few years later stocked about 125 acres with trees. On Cape Cod it has been the custom of the farmers for many years to sow the seed of pitch pine on waste lands. The method is to sow the seed with a machine or by hand in plowed furrows about 4 feet apart. The cost is estimated to average $3 to $5 per acre. While pitch pine is the tree most commonly planted, oak, ash, and other species have also been used. The plantations in eastern Massachusetts are being investigated by the

Massachusetts Forestry Association, and records have already been obtained of 10,000 acres of land artificially stocked with trees. (Pl. XXV, figs. 1 and 2.)

CAREFUL THINNING.

In many sections of the country planting by owners of small holdings is very important and should be encouraged in every way possible; but the proper care of the existing woodlands is of much greater importance. Many observing farmers have already studied this problem and manage their wood lots with great intelligence. (Pl. XXVI, fig. 1.) The extracts which follow were selected from a large number of letters written by farmers in nearly every section of the country and are given to illustrate the character of the work done.

A farmer in Rochester, Mass., writes as follows:

Ten years ago I began to cut all trees except white pine. I trim the trees as high as a man can reach easily, namely, 6 to 8 feet, leaving all limbs on the ground. I leave the outside trees, which are exposed to the sun, as a protection to the trimmed trees. I thinned and pruned the trees when about 20 years old, leaving about 200 per acre.

The following statement was received from a farmer at Wrentham, Mass.:

About thirty years ago I began to cut out the dead and unthrifty timber; also cut inferior kinds to give more room to the better ones. Cut early in winter, before deep snow interferes with the work of picking up and hauling. Never cut at the edges of a wood lot, but leave thick growth to act as a wind-break. Do not cut the same land each year, but only so often as dead wood or inferior growth makes it worth going over with ax and team.

An owner in Granville, N. Y., writes that his grandfather began in 1850 the method of work shown in the following extract:

I go over each lot and select such trees as I consider to be ripe, including all of any size with broken or dead tops. These trees I blaze or mark with an ax. I then send men to cut these trees and instruct them to use care in felling not to injure any young trees if they can avoid doing so. The tops I have worked up, so as to leave the ground clear for the next growth.

This careful work is by no means confined to the Northeast, but letters were received from men in nearly every State to the effect that a very large number of farmers endeavor to use conservative methods in cutting their wood lots. Thus, one farmer writes from Tennessee:

1. We use all the timber that blows down.
2. We cut any that seems to be diseased or dying.
3. We take the crooked, knotty, scrubby trees.
4. If we need more wood when the above kinds are used, we cut the oldest trees that seem to do the least growing.

A Virginia correspondent states:

For fuel I cut the old, dead, gnarled, crooked, and unshapely trees, leaving the straight, vigorous, and more valuable. When cutting for fence material, I take only one or two here and there, thinning out to give others more room. Tops, logs, brush, etc., are burned in winter and ashes spread among growing trees.

FIG. 1.—WHITE-PINE GROVE IN WHICH THINNING AND PRUNING HAS TAKEN PLACE. PLYMOUTH, MASS.

FIG. 2.—PLANTATION OF WHITE PINE, EIGHTEEN YEARS OLD. SOUTH ORLEANS, BARNSTABLE COUNTY, MASS.

FIG. 1.—A PITCH-PINE PLANTATION, ESTABLISHED BY SOWING. EAST BREWSTER, MASS.

FIG. 2.—LAND CUT PERIODICALLY FOR SPROUTS, WITH YOUNG GROWTH IN THE FOREGROUND. BARNSTABLE COUNTY, MASS.

A Michigan man writes that he marks all the trees he wishes to leave standing and cuts the remainder, piling and burning the brush.

A California farmer writes as follows:

In the winter season, when time will admit from farm work, I cut out all the poorest growth, leaving only thrifty trees, about 200 to the acre. I draw all brush to some clear ground and burn it. I burn all chips and trash and obtain a large amount of ashes, which I throw around my apple trees.

CAREFUL CUTTING OF SPROUT LAND.

It is well known that most hard woods send up sprouts from the stump, especially if the trees are cut before the sap begins to run in the spring. (Pl. XXVI, fig. 2.) Many farmers take advantage of this fact, and cut their woodlands clear, and then wait fifteen to thirty years for a second crop of sprouts. It is common to hear this practice vigorously condemned, but as a matter of fact, it is one of the established systems of forestry used in Europe as well as in this country. For the production of firewood it has many advantages; and if the cutting is done carefully, the growth will frequently amount to not less than 1 cord per acre per annum. Thus, New England farmers calculate that about twenty-five years are required for cleared sprout land to produce 25 cords of wood per acre. This system has been in practice since the early settlement of the country, and in many places old oak stumps may be seen from which repeated crops of sprouts have been cut and which have become, under the treatment, gnarled, misshapen, and covered with irregular knobs. As a rule, no precautions are used to assist in the prolongation of the life of the stumps, but the correspondence of the Division of Forestry shows that a considerable number of men have taken this point into consideration in cutting their sprout lands. Thus, a New Jersey farmer writes that he cuts his stumps slanting from the center like the roof of a house, taking care not to injure the bark. In this way no rain water is allowed to collect on the stump and thus hasten its decay. A number of correspondents stated that they are accustomed to cut the stumps close to the ground, so that independent roots will be formed and the wind will not break off the sprouts, as would often be the case with high stumps. Letters were received from many farmers stating that they always cut the trees in winter, as the stumps are apt to lose their sprouting power if cut during the growing season.

CONSERVATIVE LUMBERING.

The most extensive work in forestry by lumbermen has been done in the spruce forests of New York and the New England States. The pioneer of this movement was E. S. Coe, of Bangor, Me., who saw very early that if only the large trees were cut and the small ones left standing, the land could be cut over at repeated intervals. In letting contracts, therefore, he restricted the cutting to 10, 12, or even sometimes to 14 inches on the stump. As a result he cut over certain tracts a second time and obtained as large a cut as at first, using the same diameter limit. A large number of owners have followed his example and limited the cutting of spruce to a certain size, but so far as the writer is informed the cuttings have not been regulated in a systematic way, except on the tracts belonging to Dr. W. S. Webb and Hon. W. C. Whitney, in the Adirondacks, where the land has been lumbered under a system devised by the Division of Forestry. The usual method of the lumberman is to issue instructions to the choppers not to cut trees under a certain diameter on the stump, and later on the stumps in the woods or the butt logs on the landings are measured in order to see that the regulation has been complied with. On the two tracts just mentioned, however, not only is there a diameter limit for the cutting, but all trees are marked which are to be cut, and seed trees above the specified size are left when necessary. The lumbering is strictly regulated according to the following rules, and competent inspectors are employed to see that they are rigidly carried out:

(1) No trees shall be cut which are not marked.

(2) All trees marked shall be cut.

(3) No trees shall be left lodged in the woods and none shall be overlooked by the skidders or haulers.

(4) All merchantable logs which are as large as 6 inches in diameter at the small end must be utilized.

(5) No stumps shall be cut more than 6 inches higher than the stump is wide.

(6) No spruce shall be used for bridges, corduroy, skids, slides, or for any purpose except building camps, dams, or booms, unless it is absolutely necessary on account of lack of other timber.

(7) All merchantable spruce used for skidways must be cut into logs and hauled out.

(8) Contractors must not do any unnecessary damage to young growth in lumbering; and if any is done, they must discharge the men who did it.

The International Paper Company has within a few years adopted a system of restricting the cutting of spruce on a part of its lands in Maine, New Hampshire, Vermont, and New York. The method is to cut no spruce under 12 inches in diameter on the stump. Fir, however, is cut clean in order to reproduce the ground to spruce. On one tract of 120,000 acres, in New Hampshire, an inspector has been employed to watch the lumbermen to see that they do not cut any small spruce for lumbering purposes, except for camps, bridges, dams, cribs, piers, and corduroy. On a considerable amount of land, however, this company cuts the spruce clear without regard to the future production of timber.

An interesting method of forest work is that used in the southern part of New Hampshire, near Lake Winnepesaukee, where the lumbermen, in a number of cases, have left white pine trees for seeding purposes. The trees are usually spreading, scrubby specimens, which are of no great value, but which, nevertheless, would bring a small price for box boards. The lumbermen calculate that about two to five good seed trees of pine per acre, evenly distributed, usually secure an excellent natural reproduction. It is the custom, therefore, to leave standing not less than two or three spreading trees per acre.

Some of the lumbermen in Maine, in cutting second growth white pine, leave standing all trees under 12 inches in diameter, and calculate that they can return for a second crop in about twenty years.

In the Allegheny Mountains much of the lumbering does but little damage to the forest. This is usually not due to a conscious intention on the part of the lumbermen to protect the forest, but is because only a limited class of timber can be sold. Thus, one man in West Virginia writes that he cuts only the white oak, poplar, and walnut, leaving all trees under 23 inches in diameter. He states that he takes great care not to injure the young growth; that he is now cutting over a tract of 1,200 acres for the third time in twenty-six years, and that he expects to remove his fourth crop in five years more.

A novel plan of forest work has been initiated by the owner of about 4,000 acres at Kendalia, W. Va., who wishes to combine forestry with stock grazing. He is thinning the entire tract, removing the dying, overripe, or otherwise unlikely trees, and leaving all thrifty, sound specimens of all species. He then clears the underbrush and sows the ground to blue grass. The thinning is to be completed within a year or two, and the work of clearing and sowing to grass will be done gradually. It is the owner's intention to utilize the farm permanently for stock and to hold the growing timber as an investment for the future. The owner is making the experiment with the full understanding that the future value of his forest lies in the growth attained by the small trees now standing, and that when these trees are cut there will be no provision for natural reproduction. The work was begun in 1898, and 10 acres were treated in the way described in order to ascertain the expense and to test the behavior of the grass. It appears to be an entire success.

As illustrating the kind of forestry practiced by certain lumbermen in the South, the following letter is of interest:

I have just commenced to cut off 700 acres near Ohatchee, Calhoun County, Ala. I go over the land, cutting all the trees down to a diameter of 12 inches at the stump, or 2 feet above the ground. I leave all the oak and pine (longleaf yellow pine) and cut down all other growths clean, and leave the woods clean with the exception of the timber I leave to grow larger. These small trees are then thick enough, or as thick as they should be, to grow fast. I cut from this land about twenty large trees to the acre. This in log scale makes about 9,000 to 10,000 feet to the acre. I burn this land off every year, some time when the sap is not up, or any time between November and February. There are never enough leaves to make enough fire to hurt the timber by burning it once a year. I am very careful in cutting this large timber to fall it so as not to inflict wounds on the trees to stay on the ground, as this will leave defects in the timber when it is cut, say twenty years from now. I do not leave small trees unless they have straight bodies, so when they grow up they will be useful timber. Inside of five years I will begin to leave sprouts that appear, so as to form another growth after this timber, now being left, is ready to cut. I use this land after it is cleaned up for sheep and hog pasture.

The instances of conservative lumbering described in the preceding pages are but examples of work which has been carried on by a large number of lumbermen. The systems have been devised by the owners themselves, and, while in many cases improvements could be made, the work shows that much more has been done in the way of forestry than is generally supposed.

FOREST MANAGEMENT UNDER SYSTEMATIC WORKING PLANS.

It has been said that forestry consists in managing woodlands with the expectation of obtaining repeated crops of timber. Systematic forest management requires, first, the determination of the amount of timber that can be obtained at different periods, and, second, the management of the forest in accordance with a definite plan which shall secure the greatest returns in the long run.

In most instances the conservative forest management hitherto practiced in this country has been without system, and the owners have not known whether or not the methods used were successful in maintaining the productive power of the land. The first large forest put under systematic management with a definite working plan was that belonging to G. W. Vanderbilt, at Biltmore, N. C. The work was organized in 1891 by Gifford Pinchot, now the Forester of the Department of Agriculture, on about 4,000 acres. Additional tracts have since been purchased to the extent of about 100,000 acres, and the whole area has been brought under systematic treatment. An expert forester is employed to superintend the work, and there is a corps of trained rangers. A certain amount of mature poplar has been lumbered, and the system of cutting employed has been very successful in bringing about an excellent reproduction of that tree. Improvement cuttings of various species, chiefly for cord wood, are made in the portions of the tract nearest the market, and a certain amount of planting is done every year. The tract is admirably protected from fire, theft, and stock grazing, and a complete system of roads and trails is being laid out.

A great deal of the work which is being done at Biltmore would not be practical on many other large tracts (managed solely for profit) in other sections or even in the same section of the country. The kind of systematic forest management practical for lumbermen will be more along the lines practiced on the Webb and Whitney tracts, in the Adirondacks, already mentioned in the discussion of conservative lumbering.

During the past year a considerable amount of systematic forest work has been organized on private tracts under advice from the Division of Forestry. This has been the result of an offer made in October, 1898, by the Secretary of Agriculture for the Division to give advice and assistance to private owners in handling their woodlands. Within a year after the offer was made applications were received from owners in thirty-five States for assistance, the total area covered by these applications being about 1,600,000 acres. The preparation of working plans for these tracts and the supervision of their execution is now one of the important branches of the work of the Division of Forestry.

FOREST FIRES.

The first condition necessary for successful forestry is an adequate protection from fire. In sparsely settled countries, where there are large unbroken stretches of forest, this is the first problem to be solved, and until the danger is reduced to a minimum owners will not lumber with reference to the future.

In farming countries, where the holdings are small and interspersed with fields and roads, the fires can be successfully prevented by careful watching. Hitherto the majority of owners of both large and small tracts have relied chiefly on careful watching and, in case of a fire, on extinguishing it before much damage is done. Further precautions are, however, now coming into use, such as clearing wood roads, burning fire lines, piling and burning tops after cutting, etc. Some of these measures are practical only on small woodlands, but those who have tried them write enthusiastically of their success.

A farmer in Pennsylvania describes his method of protection as follows:

> I make fire lines 2 perches wide. Just before fall of leaf I cut brush to prevent return of sap. In spring I sprinkle with water to limit the extremes of fire and burn the space inside. Each year the growth is less and grass begins to grow. The cost of cutting brush is $3 to $4 per acre.

An owner of a farm on one of the small islands off the coast of Maine writes:

> We cut two strips across narrow places and cleared all brush, so that the grass would grow and, if necessary, in case of fire, the land could be plowed. The work was started five years ago and the wood nearly paid expenses. This method was adopted because of the danger of fire on the outer ends of the island, where fishermen frequently camp, and we feel that in case of fire on a point we could fight it and keep it from the best part of the island.

A Michigan farmer makes a practice of cutting roads through the forest, harrowing and seeding them to grass, and then allowing stock to graze on them. The system was initiated in 1885, and in the judgment of the owner the expenditure of about $100 per annum has been a profitable investment.

The construction of fire lines around and through the wood lot is practiced by farmers in many sections of the country. The custom is especially common among Western farmers on the plains, who have made artificial plantations. In the South the same system is used, but farmers more often burn over the whole of their land every year.

The most disastrous fires occur on large tracts, where the construction of fire lines would in many cases be impracticable. The methods used by lumbermen and other large owners to protect their property are, therefore, of special interest. The most common method, where any attempt at fire protection is made, is an organized fire patrol. Thus, some companies operating logging roads have men follow every train during the dry season to extinguish any fires that may be set by the locomotives. Other companies have extra rangers during the dry times who patrol the woods, watch campers, and in case of fires repair to them at once.

This system is well illustrated by the following letter from a lumberman in Forest County, Pa.:

In dry times we patrol especially exposed parts. In spring and autumn, during dry weather, our woodsmen all have orders, no matter what they are doing, whenever they see smoke arise, to go to it and put out the fire. It is usually done by back-firing entirely around and watching it until we are sure the fire is out. By this means we have kept serious fires from our timber when we are working. It costs us a few hundred to a thousand dollars annually. Usually successful, but not always. The outlay is profitable.

The most perfect system of fire protection in this country known to the writer is that used by Dr. W. S. Webb on his tract of 40,000 acres (Nehasane Park) in the Adirondacks. The park is divided into four sections, each watched over by an experienced woodsman, who lives at a point from which all parts of his section can be easily and quickly reached. The houses of the rangers are connected by telephone, and there is an admirable system of roads and trails. In case of fire in the park, the superintendent and the rangers are notified by telephone, and all available men are called out to extinguish it. In case of a severe fire along the railroad which traverses the park, Dr. Webb is notified by telegraph, and a locomotive is dispatched to draw the "fire service" to the scene. This consists of a large tank placed on a flat car, to which is attached a box freight car containing a small engine used to pump the water from the tank, and a complete outfit of hose, axes, and other tools used in fighting fires.

A lumberman owning 2,000 acres in Huntingdon County, Pa., describes his method of fire protection as follows:

I divide into lots say 200 acres, cut roads through, and rake all rubbish and burn it before the season gets too dry. This makes good fire-breaks. When very dry I put a watchman on for every 200 acres. The first year's cost was $400; that of succeeding years $60.

The owner pronounces the above method entirely successful, and is confident that the outlay has been profitable.

FIG. 1.—A PLANTATION OF PITCH PINE, ABOUT FIFTY YEARS OLD. SOUTH ORLEANS, BARNSTABLE COUNTY, MASS.

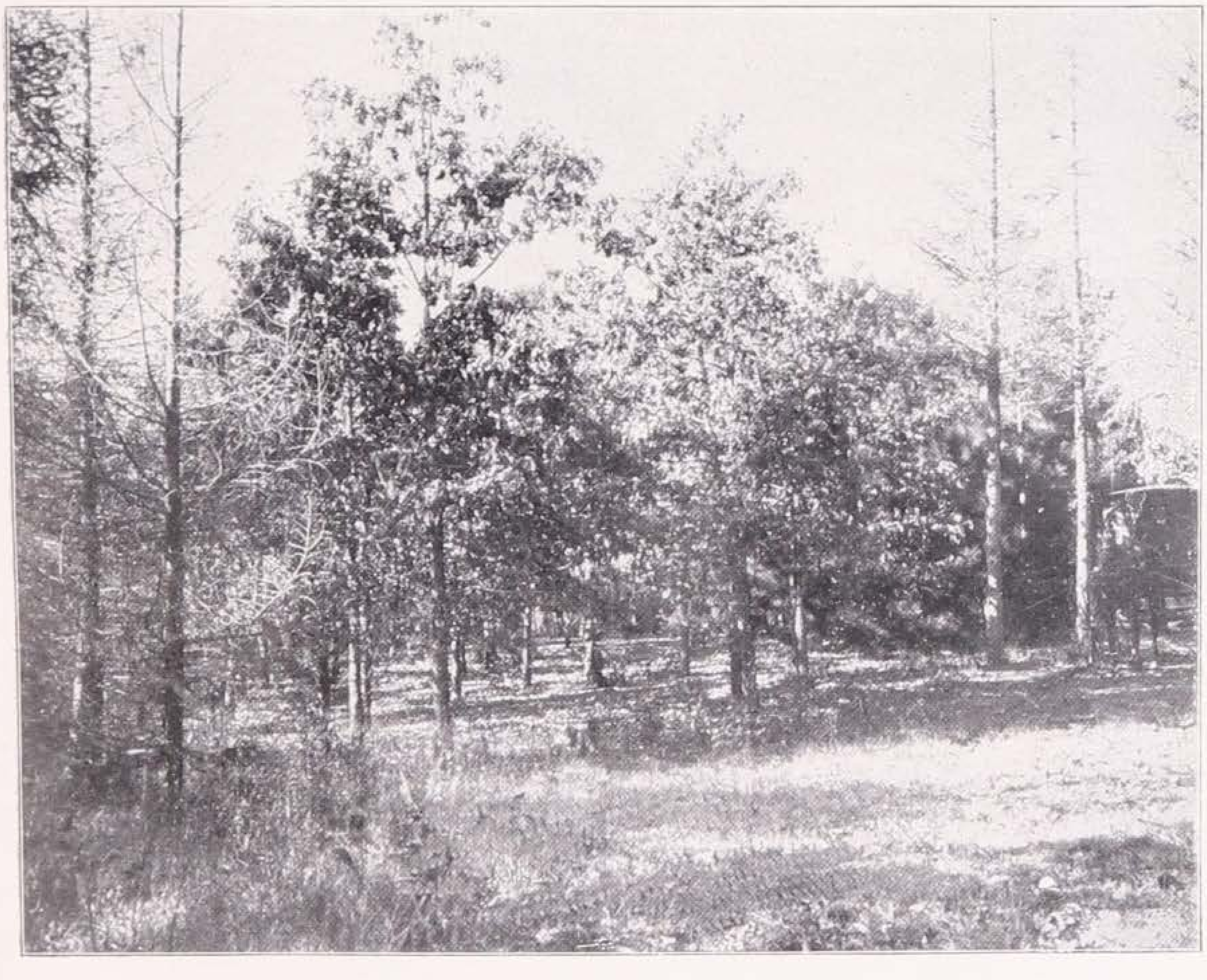


FIG. 2.—A GROVE OF WHITE OAK ESTABLISHED BY DROPPING THE ACORNS IN HOLES MADE WITH A CANE. EAST GREENWICH, R. I.

A Pennsylvania lumber company writes:

In dry times we have men watch exposed places; also have 100-barrel tank on a car, with 600 feet of 2½-inch hose. Two streams can be thrown from this tank, as there is a powerful pump attached with two connections for hose. In 1898 we expended $900 fighting fire before we rigged up the tank. This year, with more fires, the expense has not exceeded $100, and we have been able to control every fire. Not over 10 acres have been burned over this season as against 200 last year.

A Michigan man writes that he burns the tops of the felled trees in wet weather after he has finished logging, and states that the measure has been successful in protecting his timber land. He also says that after an experience of twelve years he considers the outlay a good investment.

One owner of 30,000 acres in Clark County, Wis., has for six years made a practice of clearing up and burning the tops after lumbering, and considers it a practical and profitable undertaking.

In the pine belt of the Atlantic coast it has long been the custom for many owners to let a light fire run through the forest annually, or once in several years. The fire is set in winter or early spring, when the ground is damp and it can be kept under control. The measure is very successful in protecting the standing timber, but in many cases it destroys the young seedlings, and the ultimate effect on the forest is injurious. The method of burning used in the turpentine forests is shown by the following letter from Louisiana:

We rake the dry straw (needles), grass, and chips from the base of the trees, about 3 feet all around, and the woods are burnt within the time prescribed by the Mississippi law, to lessen the growth of grass. The work was begun about eight to ten years ago, and cost about $120 for 1,600 acres. The custom of raking the ground at the base of the trees is considered as part of the turpentine business. This method is adopted by nearly all turpentine producers. The raking is done with ordinary garden rakes, and has been the means of preventing many forest fires. The raking is commenced about one week before Christmas or earlier, if the straw is done falling, and continues all through January.

The cost of raking and burning is estimated by the crop. About 10,000 boxes constitute a crop, and the cost of raking and burning is about $12 per crop. I work about 10 crops every year, and pay on an average $120 to have them raked and burned properly; and the outlay, in my judgment, has proven both wise and profitable.

The custom of burning over the forest in winter or early spring is also common among lumbermen and farmers in California and other Western States.

FOREST PLANTING.

The great bulk of the forest planting has been done in the States west of the Mississippi River. In the Eastern States, except in a few instances, the planting has been on a very small scale and usually as an experiment. Reference has already been made to the extensive planting in eastern Massachusetts, where not less than 10,000 acres have been artificially restocked with forest trees. (Pl. XXVII, fig. 1.) Nowhere else in the country, so far as the writer is informed, has so much planting been done on so limited an area. Record has been obtained of a large number of farmers who have planted from 1 to 10 acres, and there are a few instances of planting on a more ambitious scale. The plantations described in the following pages are but a few of many instances, but they show the kind of work which has been done.

An interesting plantation is that belonging to Isaac Adams, at Moultonboro, N. H., covering altogether about 50 acres, and composed of white pine and Norway pine set out about twenty-five years ago. The trees have grown admirably, and, so far as showing what planted pine will produce, the experiment is very valuable. The cost of planting in the first place was, however, much more than it would be to-day.

The experiments of J. D. Lyman, near Exeter, N. H., who planted several acres of waste land with pine, are of considerable value, because he was able to show that the cost of stocking land with trees can be reduced to about \$3 to \$5 per acre. His method was to sow the seed in hills 4 feet apart and to put from three to five seeds in each hill.

A very instructive plantation has been established by Mr. H. G. Russell, at East Greenwich, R. I., covering about 150 acres. (Pl. XXVII, fig. 2.) Like many American planters, he began with imported trees, namely, Scotch pine, Austrian pine, and Norway spruce, but later used native species. The work was begun in 1878, the intention being to form a wind-break, and in addition to provide an object lesson in forest planting.

The most extensive planting in Pennsylvania has been done by the Girard estate, near Pottsville. About 250 acres were set aside in 1881 to be treated under the methods of forestry. This tract was fenced and surrounded and crosscut by fire lines wherever there existed no roads adapted for that purpose. The trees used were white pine, Scotch pine, European larch, and white oak. The cost of planting varied from \$18 per acre for the pines to \$75 for the oaks. The planting of trees on the barren gravel at the edge of the reservoirs is of special value.

Another interesting experiment in planting in Pennsylvania has been undertaken by the Morrison and Cass Paper Company, at Tyrone. About 2,000 Carolina poplars were planted in 1898, at an expense of \$534.50. About half the trees were 10 to 16 feet high and the remainder somewhat smaller. They were planted 12 feet apart in rocky, worthless land.

The planting of trees along the banks of streams to prevent erosion has been undertaken in a number of instances. Thus, in Arkansas a correspondent states that he has planted red birch, native willows, and soft maple for 2 miles along a stream to prevent the washing of the banks. The plants were seedlings about 2 years old and were taken from the woods. Similar work has been done at Mahwah, N. J., on the estate of Theodore Havemeyer.

A CATALPA PLANTATION.

In Ohio tree planting was begun very early. In 1830 Ezra Sherman, of Preston, planted about 15 acres of locusts, as well as an avenue along the public highway for about 200 rods. In 1870, 180 trees were cut down and 1,500 posts were obtained, netting \$525. A certain amount of planting on a small scale is now done by farmers in Ohio, Indiana, and Illinois, but most of it is for the purpose of forming wind-breaks.

In most sections east of the Mississippi the natural reproduction of the forest is so abundant that planting has been little resorted to. Thus, where the loblolly pine flourishes the abandoned fields are often entirely seeded in a few years to young trees. So prolific is this regeneration that it has long been the custom in certain sections of the South to allow worn-out land to spring up to pine, and when the trees are 30 to 50 years old to clear and cultivate the land. Thus, there is a regular rotation of field and forest crops.

Natural reproduction is very prolific throughout the humid regions of the country, and old fields, if not pastured or continually burned over, eventually return to forest. Planting is very desirable for small owners, who, by the expenditure of a small amount of money or labor each year, can gradually stock the waste portions of their farms, but for lumbermen and other large owners planting on an extensive scale will, in the majority of cases, not be profitable.

On the Western plains, where timber is scarce and has a high market value, tree planting is very important, and it is here that the great bulk of the work has been done (Pl. XXVIII). Extensive tree planting on the plains was begun about twenty-five to thirty years ago. Several States, notably Iowa, Kansas, Wisconsin, Nebraska, Missouri, Minnesota, Illinois, Nevada, and the Dakotas, passed laws about that time encouraging, by bounty or exemption from taxation, the planting of forests. In 1873 the timber-culture act was passed by Congress providing that a title could be obtained to 160 acres, or a proportionate part thereof, by those who planted 40 acres or a proportionate area. While the State laws had but little immediate result and the timber-culture act was frequently a source of fraud, an impulse was given to tree planting, and the great amount of work which has been done must be traced largely to the effects of these legislative acts.

The correspondence of the Division of Forestry shows that a large number of farmers have planted trees for wood lots or wind-breaks in all the Western States. The greatest amount of work seems, however, to have been done in Kansas, Nebraska, and Iowa. The estimate given for the total planted area of Kansas in 1898 by the State board of agriculture was 159,859 acres. The total planted area in the other States has not been determined, but this question, as well as the results of the experience obtained in tree planting, is under investigation by the Department of Agriculture.

Tree planting on the Western plains was taken up not only by small private owners, but also by a number of the railroads. In 1870 the Kansas Pacific Railroad experimented with tree planting on a small scale in Kansas, and in 1873 the Atchison, Topeka and Santa Fe Railroad established four stations, planting altogether about 70 acres. The Northern Pacific Railroad established an experimental station of 40 acres at Casselton, N. Dak., and the Burlington and Missouri and the St. Paul and Sioux City railroads in the early seventies planted considerable stretches with trees to act as wind-breaks and snow-breaks. A certain amount of experimental work was also done by the St. Paul and Pacific Railroad. The most important plantation made by railroads was that belonging to the Kansas City, Fort Scott and Gulf Railroad at Farlington, Kans. The following interesting letter with reference to the work has recently been received from the firm that furnished the trees:

> We furnished the trees for the Kansas City, Fort Scott and Gulf Railroad (now the Kansas City, Fort Scott and Memphis Railroad) and for the president of the above road. This plantation [railroad] is at Farlington, Kans., and the Hunnewell plantation is 4 miles west of Farlington. At first the railroad bought the trees and the section men planted them. Possibly 50,000 trees were so planted up to 1878. We sold Mr. Nettleton, the general manager of the road, chestnuts, walnuts, and wild black cherry (a total of 12,500), white ash, and European larch. In 1878 we grew for them, under contract, 100,000 *Catalpa speciosa* and 25,000 black walnuts. In 1879 we took the contract of planting the balance of the section, they to furnish land for us to grow the seedlings on and to break the prairie sod and cross plow it when rotted; we to then plant and take care of the trees until they were from 4 to 6 feet high. They were planted 4 by 4 feet, 2,722 to the acre; we to get 1½ cents per tree when turned over. A large part—at least three-fourths—of the trees planted was *Catalpa speciosa*. A large number of *Ailanthus glandulosa* were also planted. These two kinds of trees did well. The chestnut, larch, white ash, and wild black cherry were an almost utter failure. Over 3,000,000 plants were set out. In 1881, I believe, we sold the Iron Mountain Railroad 200,000 catalpas.

In California the planting of eucalyptus has proved very profitable to a large number of farmers. The tree was introduced in 1856, and as early as 1874 there were estimated to be about 1,000,000 specimens of eucalyptus in California. No recent estimate of the acreage of plantations has been made.

No mention has been made of the planting of sand dunes at Cape Cod, Mass.; at the Golden Gate, San Francisco, and Casmalia, Cal., nor of the planting at various experiment stations throughout the country. This is all work of great value, but it is not private forestry, and it has, therefore, not been considered in this paper.

GROWTH OF THE TOBACCO INDUSTRY.

By MILTON WHITNEY, *Chief*, and MARCUS L. FLOYD, *Tobacco Expert, Division of Soils.*

TOBACCO GROWING PREVIOUS TO THE PRESENT CENTURY.

Tobacco was grown in this country long before the arrival of the first settlers. It early attracted the attention of the colonists, and for nearly two centuries was identified with their social, economic, and political development, especially in Maryland and Virginia. In Maryland it was made legal tender in 1732 (at the rate of 1 penny per pound) for all debts, including customs dues and the salaries of State officers and ministers of the gospel. The yield of tobacco in that year was 30,000 hogsheads for Maryland alone. As late as 1777 the tax levied for Baltimore County and city was fixed at 172 pounds of tobacco per poll.

THE INDUSTRY IN MARYLAND AND VIRGINIA.

At the beginning of the present century the dark export types of Virginia and the light pipe-smoking tobacco of Maryland were the only classes of tobacco grown in this country. It has been within the present century that the cigar, the lemon-yellow cigarette, the mahogany manufacturing, the Burley, and Perique types of tobacco have been developed. Samples of Maryland and Virginia tobaccos are shown in Pls. XXIX and XXX.

In 1812 the demand by foreign countries for colored tobaccos was so great that artificial heat was employed in curing. In this way the piebald, or spangled, tobacco of Virginia was developed. Until 1828 wood fires were the only artificial means known of curing tobacco. About this time flues and charcoal fires began to be used. It was not until 1865 that flue curing entirely superseded charcoal fires in the production of the bright yellow varieties, now so popular and used as cigarette, plug, and twist wrappers.

In 1825 the amount of tobacco produced in Maryland was about 15,000 hogsheads; in 1846 it was 41,000 hogsheads, and in 1860 it was 51,000 hogsheads, this being the largest yield ever produced in that State. During the civil war the yield decreased, and in 1865 it was only 25,000 hogsheads. In 1878 the yield again increased to 46,000 hogsheads, while in 1890 the lowest production of the State was recorded, 14,000 hogsheads. In 1892 the yield rose to 27,000 hogsheads. The Maryland tobacco is consumed principally in Holland, France, and Germany.

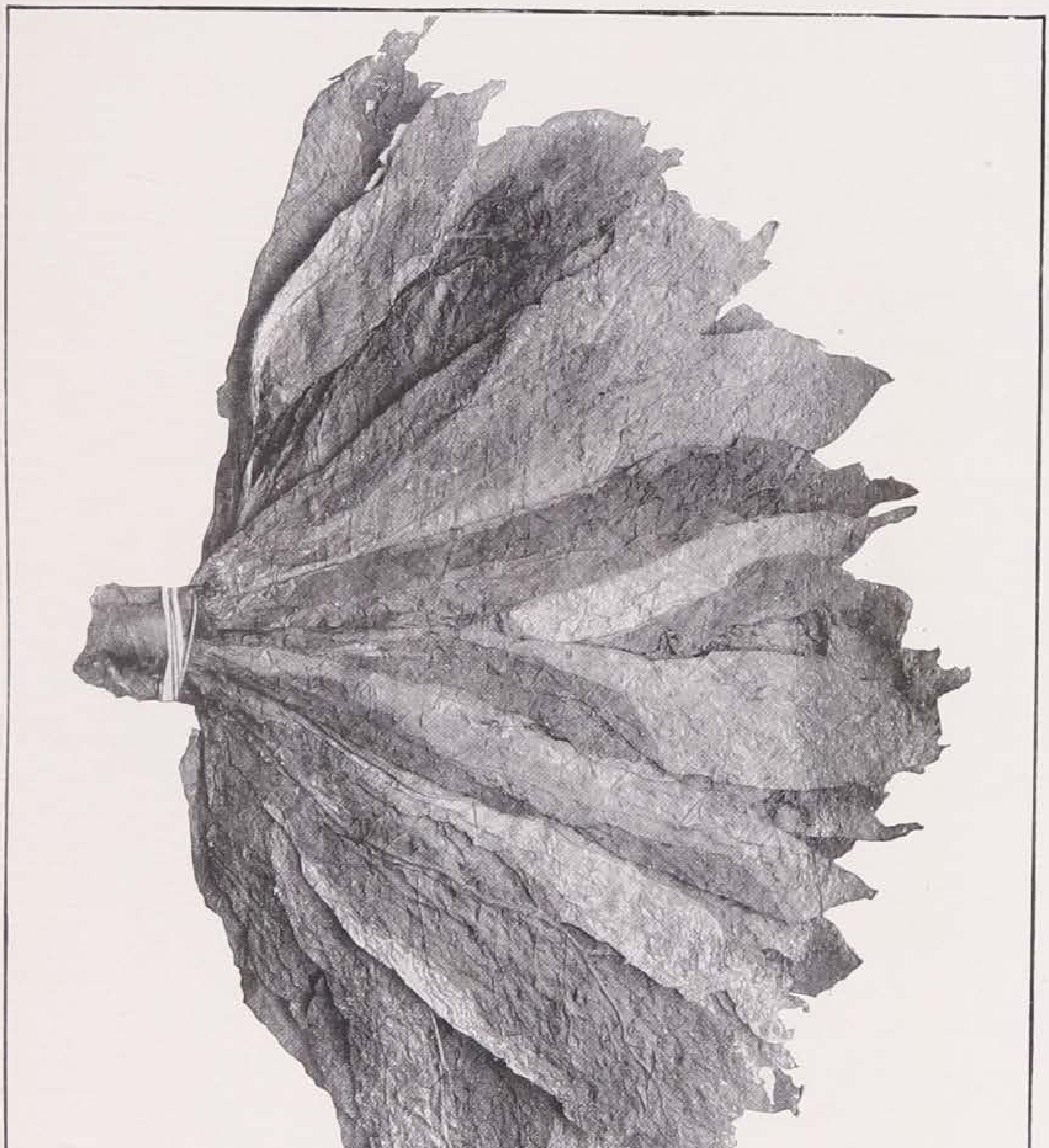
EXTENSION OF THE INDUSTRY.

Although some tobacco was grown during the time of the early settlements in Pennsylvania and New England, the first real extension of the industry was westward, in Kentucky and Tennessee. In 1785 tobacco production was of considerable importance in northern Kentucky and the adjoining counties of Ohio, while in the central and southern portions of Kentucky and Tennessee this industry came into prominence about the year 1810. The tobacco produced here was the dark, export type that has always prevailed in these localities. Up to the year 1833 by far the largest part of the tobacco grown in these two States was sent by the planters in boats to New Orleans for shipment to foreign countries. In that year, however, warehouses were established in Clarksville, Tenn., and soon others sprang up in Louisville, Ky., and in the surrounding towns of these States.

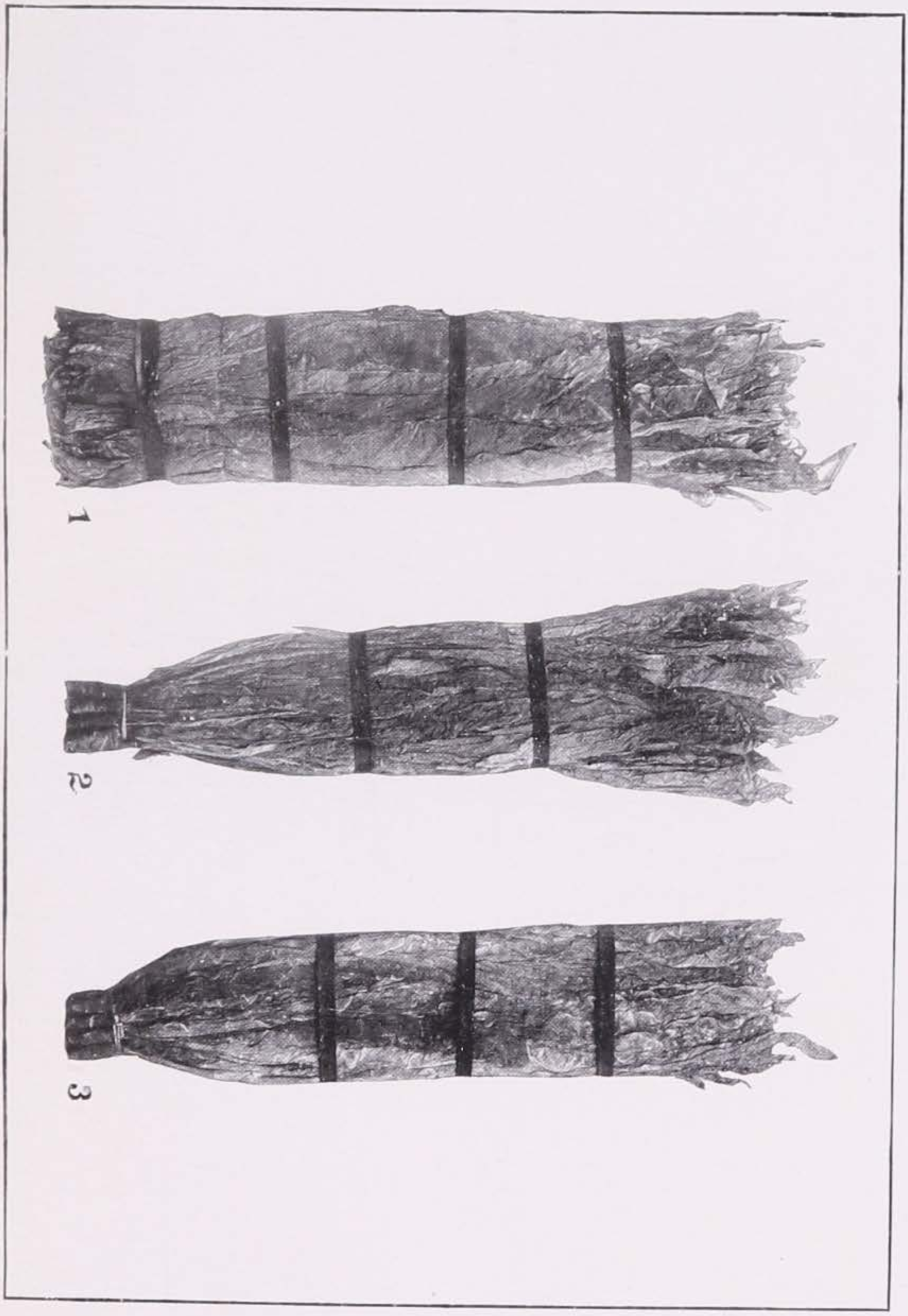
The first crop of lemon-yellow tobacco was produced in 1852 on a sandy ridge in Caswell County, N. C. (See Pl. XXXI.) This tobacco was received with such special favor that its cultivation spread rapidly in Caswell County and also in Pittsylvania County, Va. During the civil war there was almost an entire abandonment of its production, but after the war attention was again called to this tobacco as being very desirable for plug fillers and wrappers. As flue curing came into general use about this time, a much superior article was produced. The price rapidly rose with the increase in the demand, and the cultivation extended into other counties in North Carolina and Virginia and spread into South Carolina and eastern Tennessee. In 1876 there were 43,000 acres planted in this tobacco, yielding 20,000,000 pounds; in 1879 the acreage was 57,000, yielding 26,926,000 pounds. Since that time this tobacco has continued to grow in popularity and the increase in acreage still continues.

The manufacture of cigarettes began about 1864, in which year 19,770,000 were made. These apparently did not take well, as in 1869 the number of cigarettes manufactured was only 1,750,000, but since that time the annual output has steadily and rapidly increased.

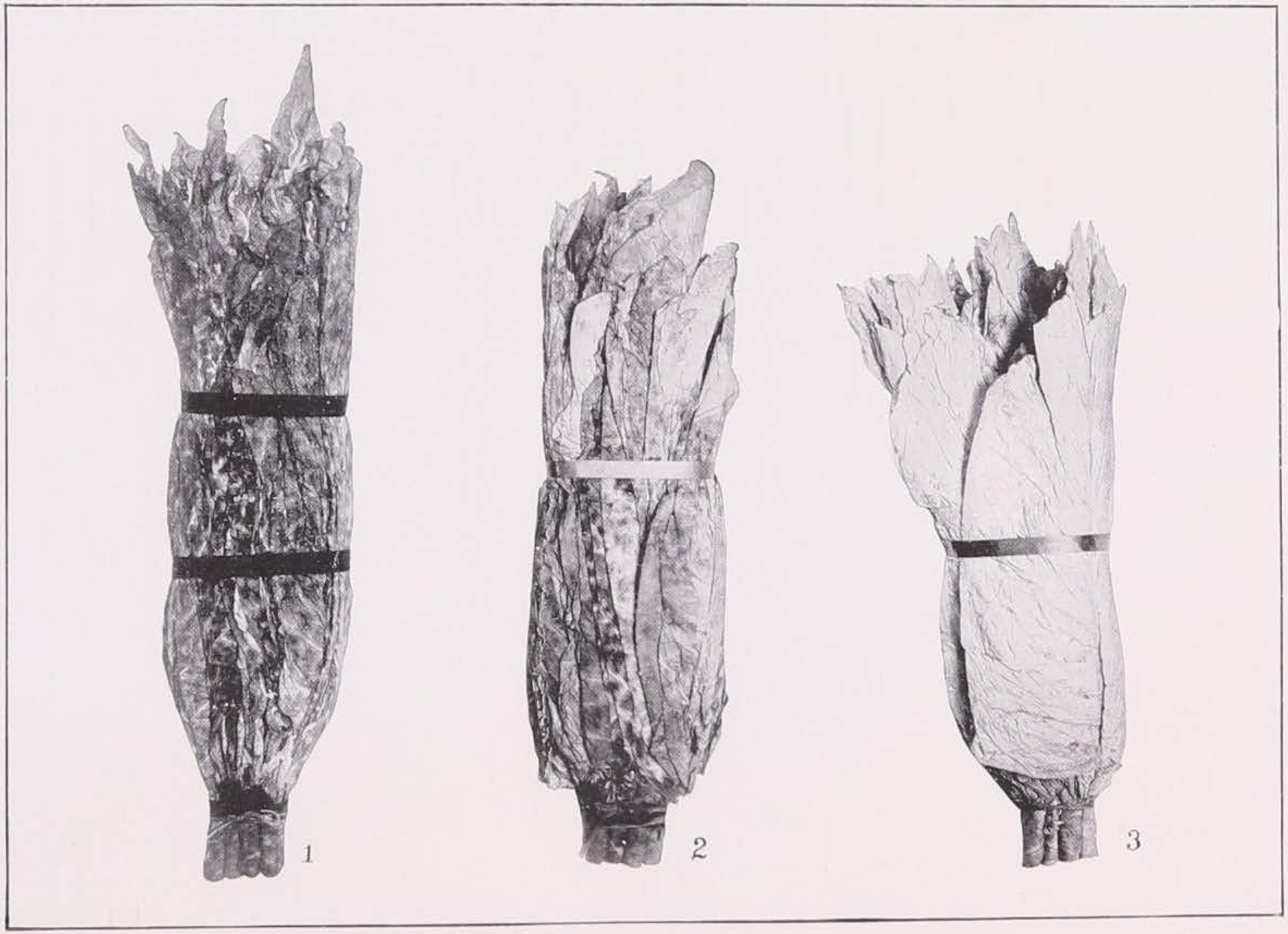
In 1864 the White Burley tobacco was originated through a sport from the Red Burley in Brown County, Ohio. This tobacco at once found favor as coming midway between the light smoking varieties of Maryland and the dark export types of Virginia, Kentucky, and Tennessee. On account of the absorbent powers of this leaf, it is particularly well adapted to plug fillers and plug and twist wrappers. The finer types are used for cigarette cutters and wrappers, while the light, flimsy, overripe bottom leaves are used for pipe smoking. The cultivation of this tobacco rapidly extended over the limestone area



MARYLAND SMOKER: BRIGHT "COLORY" LEAF.



VIRGINIA EXPORT TOBACCO: 1, ENGLISH OLIVE-GREEN STRIPS; 2, OLIVE-GREEN LEAF; 3. AUSTRIAN A.



CIGARETTE AND MANUFACTURING TOBACCO: 1, DARK MAHOGANY; 2, LIGHT MAHOGANY; 3, BRIGHT LEMON-YELLOW.

of southern Ohio and the central and northern sections of Kentucky. The cultivation of this tobacco is still confined to the limestone soil of this area. Packages of White Burley tobacco are shown in Pl. XXXII.

CONNECTICUT TOBACCO AND THE CIGAR INDUSTRY.

Tobacco was grown in the New England colonies during the years from 1640 to 1650, but from that time up to the early part of the present century it was almost abandoned. In 1825 the industry had been revived and developed to such an extent that the first warehouse was established at Warehouse Point, Conn., where 3,200 pounds were packed and shipped to New York. In 1840 tobacco became a general crop, about 720,000 pounds being produced in the Connecticut Valley. In 1842 the yield had increased to 2,000,000 pounds, and in 1845 to 3,450,000 pounds, at which time the cultivation was extended into the Housatonic Valley. About 1833 the broad-leaf variety, having a silky, delicate leaf with regular veins, nearly tasteless and of fine texture and finish, was originated. (See Pl. XXXIII.) Previous to 1845 the price ranged from 7 to 4 cents per pound, but in 1847 it rose to 40 cents per pound.

During the first part of the present century the Connecticut tobacco was recognized as being essentially different from the Virginia types, and it began to be used in the manufacture of cigars. About 20,000 pounds of tobacco were produced in the Connecticut Valley in 1801, about which time the making of cigars was begun in a small way, the first factory being established in 1810. During the early development of this industry cigars were peddled through the country in wagons. It was about this time that the first importation of Cuban cigars of any consequence was made.

The following shows the gradual increase in the number of cigars manufactured in the United States from 1860 to 1892:

Number of cigars manufactured in the United States in 1860, 1875, 1885, and 1892.

	Number
1860	199,000,000
1875	1,926,000,000
1885	3,358,000,000
1892	4,548,000,000

The first tax on cigars, chewing and smoking tobaccos, and snuff was imposed by act of Congress of July 1, 1862, which took effect September 1 of the same year. The first tax on cigarettes was imposed in 1864. Licenses for dealers and manufacturers were not required until 1868.

INTRODUCTION OF TOBACCO IN VARIOUS STATES.

PENNSYLVANIA.—The cultivation of tobacco in Pennsylvania began in 1689, but little attention was paid to the industry until 1828, when it began to be of commercial importance. In 1840 Pennsylvania produced 325,000 pounds of tobacco in York, Lancaster, and Dauphin counties, the present tobacco centers of the State. In 1845, in consequence of the Mexican war and the increased value of wheat, the cultivation of tobacco declined; but it developed rapidly between 1849 and 1859. In 1859 the yield was over 3,000,000 pounds. There was little increase in the yield until 1870; and in 1879, 36,900,000 pounds were produced, at which time Pennsylvania ranked third among the tobacco-growing States of the country.

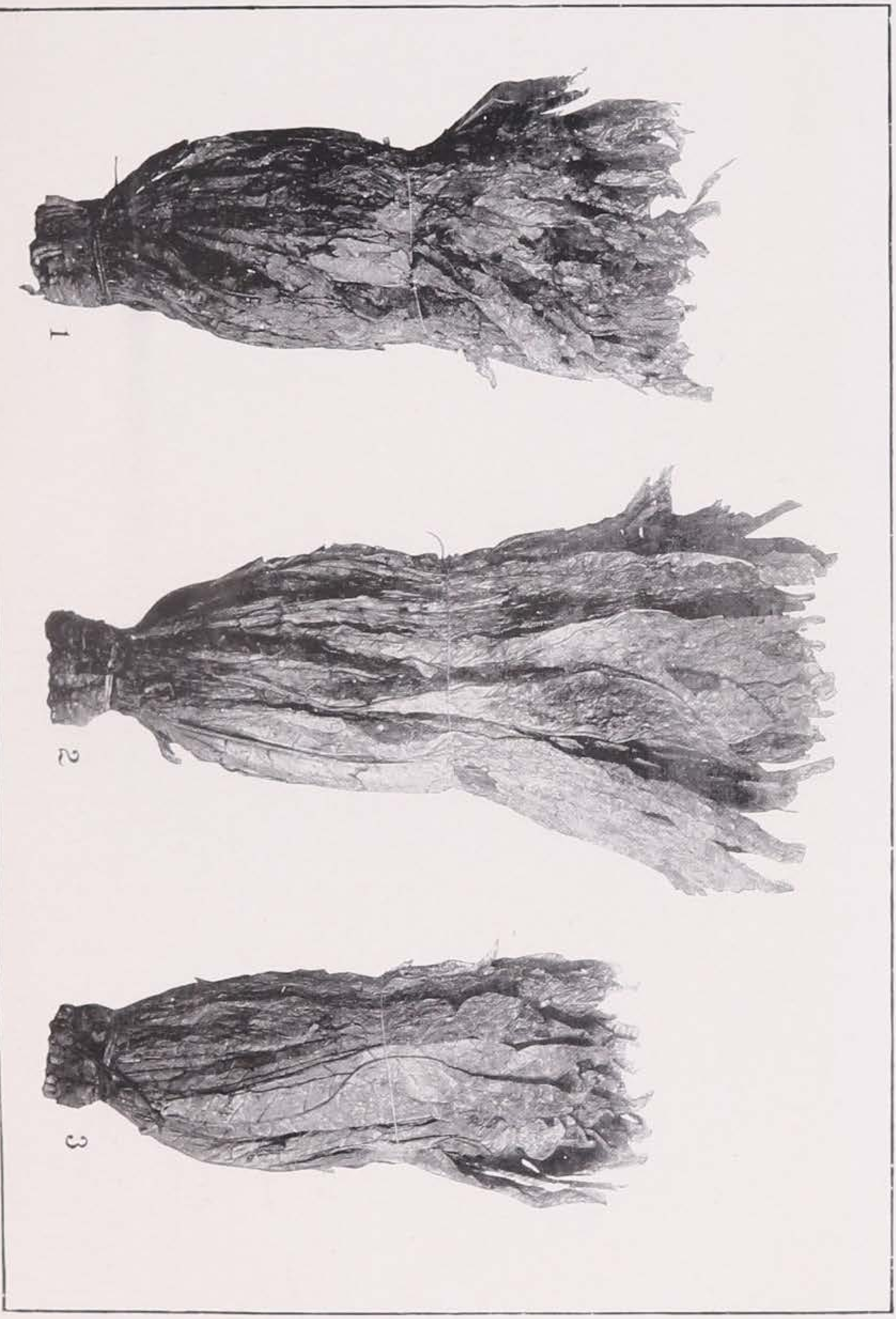
OHIO.—Cigar tobacco was first grown in Ohio in 1838, seed having been brought from Connecticut. In 1850 some 800,000 pounds of the seed-leaf variety were produced. During the years 1863, 1873, and 1880 the yield reached 1,200,000 pounds. The Little Dutch was introduced into Ohio from seed imported from Germany about 1869. In 1879 the total yield of this variety was about 500 cases. The Zimmer Spanish (Pl. XXXIV), a hybrid of the Cuban variety, was introduced about 1878. The Little Dutch and Zimmer Spanish, especially the latter, found great favor as cigar fillers. This largely increased the production of these tobaccos, supplanting to a considerable extent the seed-leaf variety.

NEW YORK.—The introduction of tobacco into New York State occurred in the year 1845; in 1855 Onondaga County alone produced 500,000 pounds, and in 1863 the cultivation had greatly extended and had reached considerable importance in several counties. From 1862 to 1864 New York tobacco brought a good price, selling for as much as 30 cents per pound. From this time on the price has varied greatly, ranging from 5 to 25 cents, and at times even to 30 cents per pound. In 1879 the crop of the entire State was estimated at 6,480,000 pounds.

WISCONSIN.—Tobacco was introduced into Wisconsin in 1850, when 1,260 pounds were produced; in 1860 the yield was 87,000 pounds; in 1870 it was 960,000 pounds, and in 1889 it was 19,123,000 pounds.

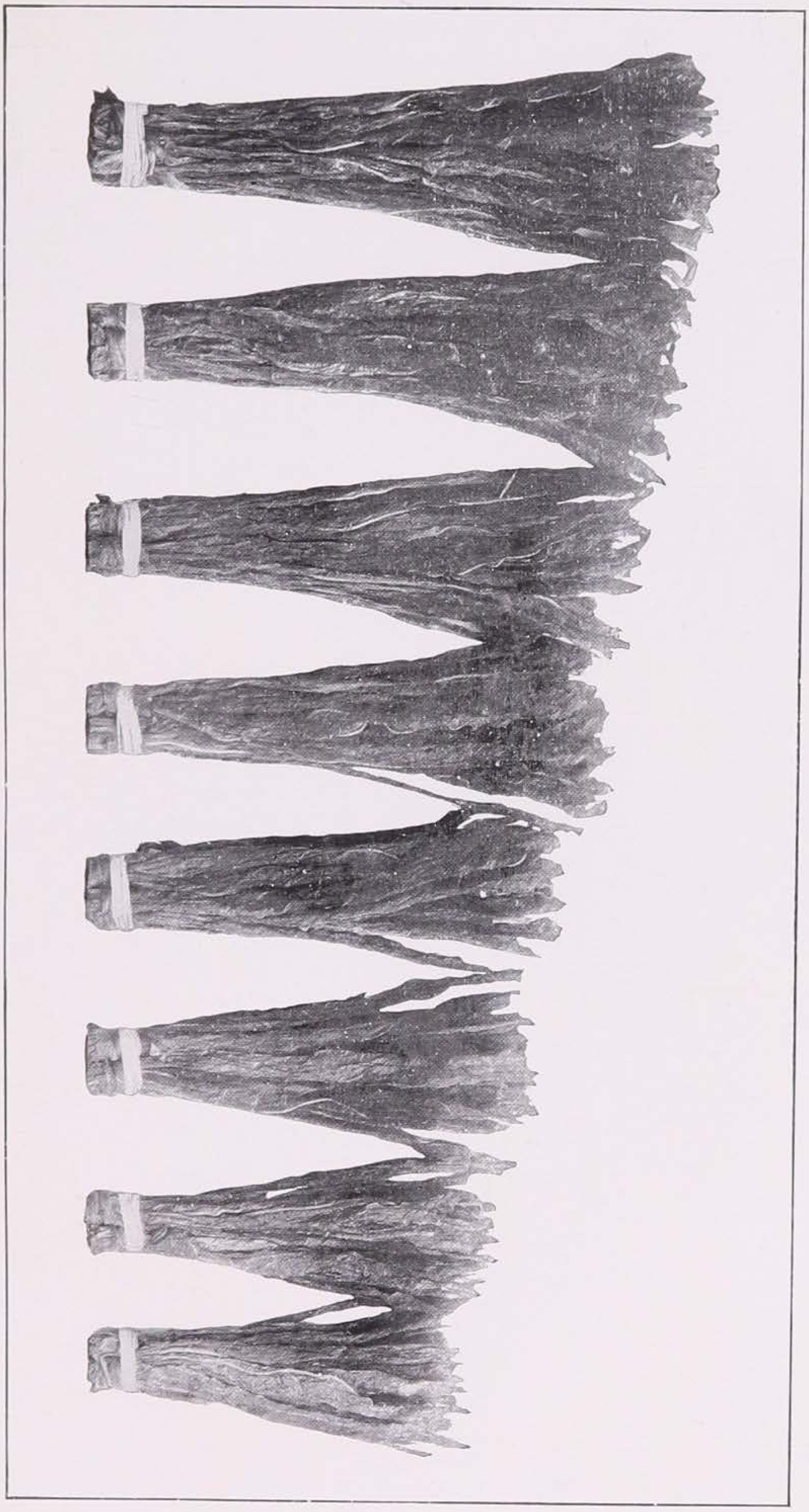
FLORIDA.—Tobacco was introduced into Florida about the year 1829; ten years later this tobacco had taken a place of considerable importance as a cigar-wrapper leaf, being especially noted for its broad, silky, beautifully spotted leaf. This is still remembered as the "Old Florida speckled leaf," the cultivation of which was entirely abandoned at the outbreak of the civil war. About the year 1888 attention was again called to the possibility of producing a desirable cigar leaf in Florida; but with the importation to this country of the Cuban tobacco, which began in large quantity in 1860, and of the Sumatra four years later, the market had changed and the "Old Florida" was no longer acceptable to the cigar trade. The Cuban and Sumatra types have formed the basis of the present development of the tobacco industry in Florida. (Pl. XXXV.)

LOUISIANA.—The culture of tobacco was begun in the State of Louisiana about the time of the settlement of New Orleans. In 1752 the



WHITE BURLEY TOBACCO: 1, FLYER, OR TRASH; 2, GOOD LEAF; 3, RED TOP FILLERS.

CONNECTICUT CIGAR-WRAPPER LEAF: 1, BROAD LEAF; 2, HAVANA SEED LEAF.



OHIO ZIMMER SPANISH CIGAR-FILLER LEAF.

Government of France offered to purchase all of the tobacco raised in that province at a price equivalent to \$7 per hundred pounds. During 1793 and 1794 the production of tobacco was stimulated by the ravages of insects on the indigo plant, which, previous to this time, had been a staple crop. In 1802, 2,000 hogsheads of tobacco were exported from New Orleans, and the culture had extended along the Mississippi River as far north as Natchez. As this tobacco had no particular excellence, it was soon supplanted by the Kentucky and Tennessee tobaccos, which were of a much superior quality. In 1824 the Acadians introduced a new method of curing, by which the tobacco was cured, under intense pressure, in its own juice. This Perique tobacco, for such is the name of the Louisiana variety, while very strong, has peculiar properties which are acceptable to pipe and cigarette smokers, especially when mixed in small proportions with other tobacco. On account of the long and laborious method of curing, the cultivation has never extended beyond two or three parishes in southern Louisiana; nor has it been placed upon a successful commercial basis, except among the Acadians. The greatest yield of this tobacco in any one year has not exceeded 100,000 pounds, and, until recently, the average yield was about 50,000 pounds. The price of the Perique tobacco had been uniformly \$1 per pound, until the extension of the area under cultivation within the last few years; since then the price has fallen to about half that amount.

REQUIREMENTS OF THE FOREIGN TOBACCO TRADE.

THE IMPORTANT COUNTRIES FOR THE AMERICAN TRADE.

The most important countries for the American tobacco trade, in the order of the quantity used, are Great Britain, Germany, Italy, Canada, Spain, Austria, Switzerland, France, Belgium, Holland, Africa, Mexico, Central America, South America, and the West Indies. Each country differs in its requirements and also in the character of the leaf used. As all of these countries are supplied from the same section, and as the differences in the tobaccos to a casual observer are slight, it requires considerable experience on the part of the packer to assort the various tobaccos into the grades suitable for each country and to put the goods in the condition required by the particular country for which they are intended.

QUALITIES REQUIRED.

In the matter of quality Great Britain requires the best leaf and pays the highest price; Austria comes next; while Italy, France, and Spain follow in the order named. Great Britain demands a large leaf, olive green in color and so heavily smoked in curing that the odor of hard wood is apparent in the leaf. (Pl. XXX, figs. 1 and 2.) The green tint is secured by harvesting the leaf before it is fully ripe.

A tobacco that gives promise of being suitable for the English market is harvested at an earlier stage of ripeness than for any other country. On account of the high import duty (about 87 cents per pound) on tobacco imported into England, it is usually stemmed before leaving this country and packed very dry.

Austria takes two grades of leaf—the Austrian A (Pl. XXX, fig. 3), a large leaf, medium to light brown in color, of medium body, and about 26 inches long; and Austrian B, a leaf of about the same quality, 22 inches long.

Italy takes four grades of tobacco. The Italian A is practically the same as the Austrian A, except that preference is given to a dark-brown color, and is used for the same purpose, that of cigar wrapper. Italian B is the same as Italian A, only shorter; Italian C1 is a dark, short, heavy-bodied leaf, used for cutting purposes; while Italian C2 is a trashy lug.[1]

France requires three grades. The French A is a leaf 20 inches long, which, in Virginia, is made black by steaming and hard pressure in the hogsheads while hot; French B is the same grade as French A, 18 inches long, while French C is a smooth lug, 16 inches in length, used principally for snuff. Formerly the French Government took the best heavy-bodied tobacco of Virginia, but since the Regie contract system[2] has been introduced the quality of the leaf used has gradually lowered.

Spain uses very little of the Virginia tobacco, requiring a leafy lug, which can be obtained to a better advantage in Kentucky and Tennessee. That country uses four grades, differing in length, cleanness, and soundness of the leaf.

Africa takes a long, narrow leaf of heavy body, which is made very black by steaming and packing under heavy pressure in the hogshead while the tobacco is still warm. Oil is applied by means of a sponge to each layer as it is packed. This same grade of tobacco is also used in the Canary Islands and West Indies, and is packed in a similar manner, except that the oil is omitted.

All dark export tobaccos are cured with open hard-wood fires, the English trade demanding extra heavy smoking in curing. There is a slight difference between the export tobacco of Virginia and that of Kentucky and Tennessee. The Virginia tobacco, generally speaking, is of better quality than the Kentucky and Tennessee grades, and more of it is used for the domestic market. On account of the high import duties of some of the foreign countries and the low prices paid by the Regie Governments, the better qualities of these tobaccos are used in this country for manufacturing purposes.

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[1] Lugs are the second pair of leaves from the bottom of the plant.

[2] The term applied to the system under which in certain countries a tobacco monopoly is maintained by Government and all purchases of leaf tobacco are made by Government agents.

The farmer assorts the tobacco roughly into lugs, good leaves, and top leaves; but the final grading and treatment are given by the packer, who also decides to which country the various qualities of tobacco shall be sent. If the tobacco needs darkening, to meet the demands of any particular trade, the desired shade is obtained through various ways of manipulating and packing the tobacco.

MANUFACTURING AND SMOKING TOBACCOS.

The light tobaccos produced in Maryland are air cured, while a similar type grown in eastern Ohio is largely cured by wood fires. These tobaccos are used exclusively for pipe smoking and cigarettes, the following grades being made by the packers: Fine yellow, medium bright, good ordinary "colory," fine red, fine seconds, medium seconds, and lugs. Nearly all of these goods are exported, the best markets being found in France, Germany, Holland, Austria, and Belgium.

Almost the entire yield from Maryland and eastern Ohio is sold in Baltimore, where five large warehouses have been established for the inspection of these goods by State officers. As soon as these tobaccos are entered in the warehouse a sworn and bonded inspector draws four samples from each hogshead, taken from different places and at equal distances apart, beginning near the bottom of the hogshead. These four samples, or hands, are tied together, as shown in Pl. XXIX, and are sealed and labeled with the name of the owner, the number of the hogshead, its net and gross weight, and the name of the inspector. The agents of foreign countries buy exclusively from these samples; when the goods are shipped the samples are also forwarded, so that the goods on reaching their destination can be compared with the samples from which they were bought. If there should be more than 10 per cent of tobacco in the hogshead poorer than the sample, the inspector, who is under bond, becomes liable for such difference.

The White Burley (Pl. XXXII) is entirely air cured, except in exceedingly damp weather, when wood fires may be used. This tobacco is assorted by the farmer into the following grades: Flyers, the first two bottom leaves, which are overripe and very trashy; common lugs, the next two leaves; good lugs; bright leaves; long red; short red, and top leaves. This tobacco is packed in hogsheads by the farmer and inspected in the same manner as the Maryland tobacco, but, unlike the latter, it is sold at auction in the warehouse.

Not more than 10 per cent of the White Burley is exported, but on account of its great absorbent powers it is highly prized in this country for twist and plug chewing tobaccos. The flyers are used for pipe smoking, the heavy-bodied top leaves for plug and twist fillers, while the best leaves are used for cigarette, plug and twist wrappers, and for cutting purposes.

The bright yellow and mahogany tobaccos (Pl. XXXI) are cured entirely by flues, a method which cures very quickly, not more than four days being required in the process. As soon as the tobacco is put into the barn the fire is started and is kept going night and day until the tobacco is thoroughly cured to the desired color. This tobacco, which is sold at auction in loose piles in the warehouse, is largely consumed in this country, being used for plug and twist wrappers, cigarettes, and finecut chewing and smoking tobaccos. The broad scope of this type makes it exceedingly popular and the acreage is rapidly increasing. Recently this tobacco has come into favor with foreign countries, Japan having lately placed a large order for this grade.

DOMESTIC CIGAR TOBACCOS.

The cigar types are almost entirely consumed in this country, and, in addition, large quantities of Cuban and Sumatra tobacco are imported. Domestic cigars are made up of wrappers, binders, and fillers, which come from different districts. The Connecticut Valley produces two types of wrapper leaf, the broad leaf and Havana seed leaf (Pl. XXXIII), both varieties being air cured, packed in cases holding about 300 pounds, and left to ferment during the winter, spring, and summer months. This tobacco is sampled and sold at private sale, the packing usually being done by those who buy the tobacco from the farmers.

The broad-leaf variety has a broad silky leaf, very elastic, about two-thirds of the leaf from the tip possessing rich grain and color. Small veins are also a characteristic of this leaf. There is only one small area in the Connecticut Valley adapted to the production of this type.

The leaf of the Havana seed is smaller than the broad leaf, much narrower, and is exceedingly thin and silky, but possesses less elasticity and covering quality. It does not possess the rich grain of the broad leaf; the middle and lower parts are glossy and have large veins. This portion of the leaf is not desirable for wrapper purposes. The heavier leaves and those slightly damaged or of uneven color are used as binders. Badly torn leaves and the trash are not suitable even for fillers, but are sold at a low price for export tobaccos. Both the broad leaf and Havana seed are graded into light, medium, and dark wrappers, and light and dark seconds, all grades being arranged in four lengths. The Connecticut wrapper competes with the imported Sumatra, being the nearest to it of any of the domestic tobaccos except that grown in Florida from the Sumatra seed.

The tobacco produced in Pennsylvania is characterized by a long, broad leaf. It is air cured and packed in the same way as the Connecticut Valley tobacco. The Pennsylvania tobacco has a dark, heavy-bodied leaf, unsuited for wrappers, but used mainly for fillers and binders. Some good wrapper leaf is grown on the light alluvial soils near the rivers. As a filler leaf this tobacco competes with the Zimmer Spanish, Little Dutch, and Florida-grown Cuban, and it is used mostly in the production of stogies, cheroots, and other low-priced cigars. This tobacco is assorted by the packers into the following grades: 18-inch, 20-inch, 22-inch, and 24-inch light and dark wrappers and binders, the shorter sizes being graded as fillers, and called Pennsylvania B's.

The New York tobacco comes between the Pennsylvania and Connecticut leaf, and contains a small percentage of desirable wrapper leaf. It is graded and packed in a manner similar to that employed in Connecticut.

Wisconsin produces only a binder leaf, which is frequently used with the Connecticut wrapper and the Pennsylvania or Ohio filler. It is graded and packed like the Connecticut tobacco.

Ohio produces mainly a filler crop of Zimmer Spanish and Little Dutch varieties. The Zimmer Spanish is a small leaf, in appearance closely resembling the imported Cuban tobacco. This type was originated about twenty years ago, since which time it has rapidly grown in favor as a filler for domestic cigars, being considered by the trade the best filler leaf grown in the United States. This tobacco is graded more carefully than any other tobacco grown in this country, except that grown in Florida. The Cuban method of fermentation is being adopted by those who handle the Zimmer Spanish. The Little Dutch is a close second in popularity to the Zimmer Spanish. It is manipulated in the same manner, but the grading is not so closely or carefully made. The leaf is larger than the Zimmer Spanish, and departs further in appearance from the imported Cuban. A small quantity of seed leaf, known as Gebhard, is produced in Ohio as a wrapper leaf, but as it is inferior to the Connecticut the acreage is rapidly diminishing. The Florida-grown Cuban tobacco, which is just coming into prominence, is regarded by some manufacturers as greatly superior to the Zimmer Spanish, being nearer to the imported Havana in appearance and quality and selling at a much higher price than the Zimmer Spanish.

There are two types of tobacco grown in Flordia, one from seed originally imported from the island of Cuba, the other from the island of Sumatra. The Cuban seed has retained the characteristic size and appearance after being planted for seven consecutive crops; but the Sumatra seed, after two or three seasons, begins to assume the character of the Cuban plant. For this reason it is customary, in order to preserve the desired Sumatra characteristics, to save enough seed from the first or second crop to last for eight or ten years and to plant each succeeding crop during this period from this seed.

The Florida-grown Cuban tobacco is used especially for filler purposes. Although good wrappers are sometimes obtained, which closely resemble the best imported Cuban wrappers, there is a prejudice against these, owing to the fact that they have considerable body, thus requiring more pounds to wrap a thousand cigars. In point of usefulness and appearance these wrappers do not compare favorably with the Sumatra type.

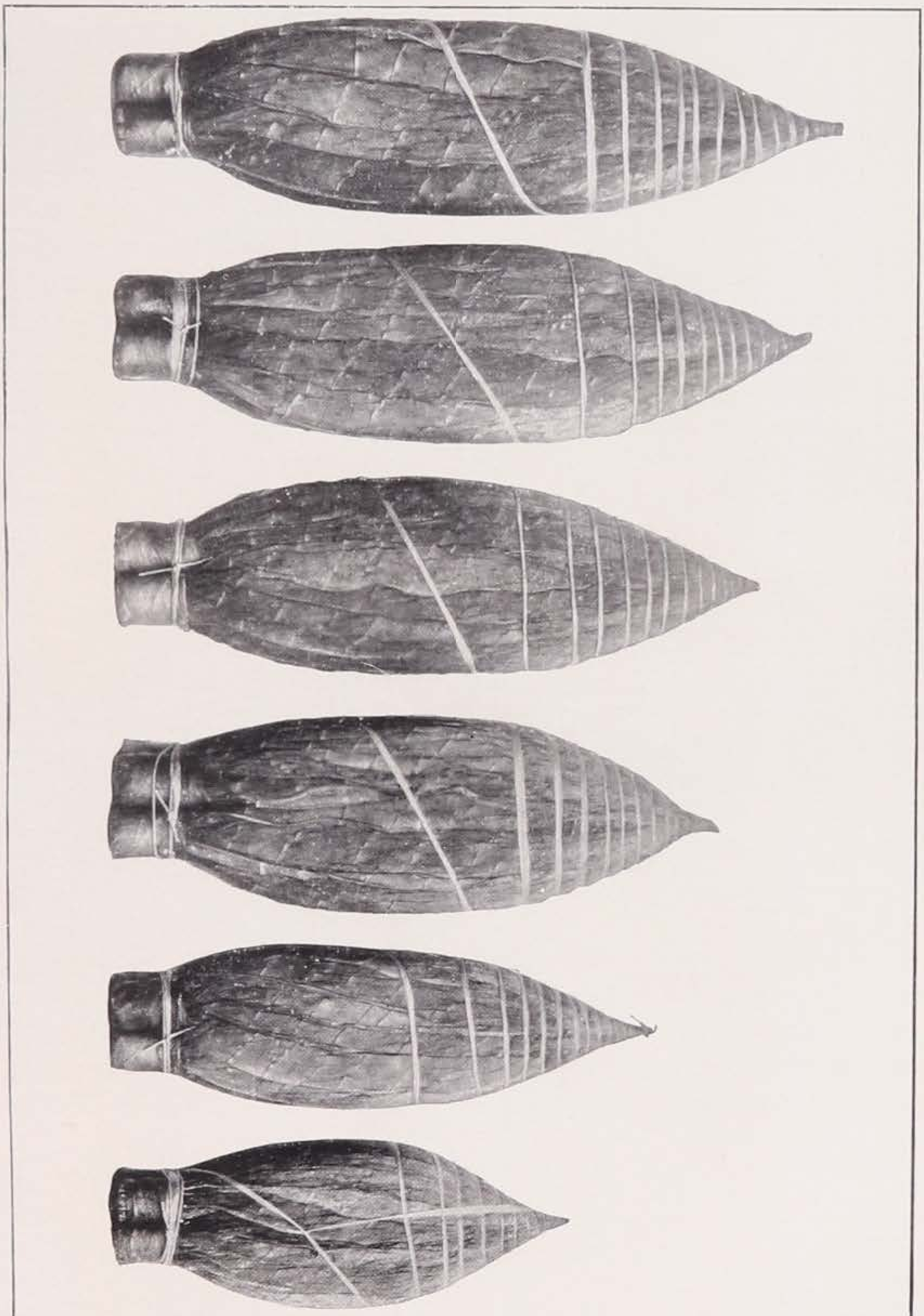
The Forida-grown Cuban filler closely resembles the imported Cuban leaf in size, shape, and general appearance. It has good body and aroma, although the specific aromatic quality and flavor of the best Cuban tobacco have not yet been obtained. The tobacco is carefully fermented, very much as in the Cuban process, and is afterwards carefully sorted and graded according to color, body, and length. It is then made into carrots (see Pl. XXXV) and baled in identically the same way as the Cuban package. This tobacco has taken well with the domestic trade, as is evidenced by the fact that it brings the highest price of any domestic filler leaf, a good packing of clean, sound leaves selling for 40 cents per pound. The Florida-grown Cuban wrapper, although constituting a very small proportion of the crop, brings from 75 cents to $1.50 per pound.

The Florida-grown Sumatra is essentially a wrapper leaf that has been highly developed during the past few years. While the first crops gave in most cases only about 20 per cent of wrappers, the proportion has now been increased to 70 and 80 per cent, under the most careful methods of cultivation. This crop is so valuable that the land is now shaded with cheese cloth, placed on wood frames 9 feet high, and irrigation is used in addition by some of the larger planters with most gratifying success. The Florida-grown Sumatra closely resembles the imported leaf in size, shape, texture, grain, and general appearance. It is extremely thin and very elastic. The most desirable sizes are 14, 16, and 18 inches. The best crops will average about 200 leaves to the pound. Two pounds will cover 1,000 cigars. This makes it a cheap wrapper for the manufacturer, even at the high price of $1.50 to $2 per pound. Choice selections have sold by the bale as high as $3 and $4 per pound, although the proportion of these very high grades is yet very small, requiring infinite care and great expense in sorting. This tobacco is all primed, that is, each leaf is picked when ripe, and great care is exercised in fermenting, grading, and assorting.

STATISTICS OF MANUFACTURED TOBACCO, SNUFF, CIGARS, AND CIGARETTES.

The total receipts by the Government, from the internal-revenue tax on tobacco from all sources during the fiscal year ending June 30, 1899, amounted to $52,043,859.05. In the fiscal year 1898 there were registered 3,186 manufacturers of tobacco, including plug, pipe smoking, and cigarette, and 115 snuff manufacturers. There were 30,856 cigar manufacturers during the same period.

The following table shows the amount of manufactured tobacco and



FLORIDA CIGAR FILLER, CUBAN SEED.

the number of cigars and cigarettes made during the past nine years, the period ending on June 30 of each year:

Statistics of manufactured tobacco, snuff, cigars, and cigarettes, 1890–1898.

Year.	Manufactured tobacco.	Snuff.	Cigars.	Cigarettes.
	Pounds.	*Pounds.*	*Number.*	*Number.*
1890	243,427,008	9,434,746	4,228,528,258	2,505,167,610
1891	259,855,085	10,674,241	4,422,024,212	3,137,318,596
1892	264,412,767	11,426,927	4,674,708,260	3,282,001,283
1893	238,587,702	11,952,736	4,341,240,981	3,666,755,959
1894	257,050,444	11,582,838	4,163,641,327	3,620,666,804
1895	263,404,840	10,887,709	4,099,137,855	4,237,754,453
1896	248,708,581	12,708,919	4,048,463,306	4,967,444,232
1897	283,320,857	13,768,455	4,431,050,509	4,631,820,620
1898	261,532,298	13,607,631	4,915,663,356	4,685,783,897

For 1899 the figures for manufactured tobacco and snuff are not obtainable separately, but the combined total for the two articles was 266,661,752 pounds. During the same year there were made 4,542,016,570 cigars and 4,590,388,430 cigarettes.

STATISTICS OF LEAF TOBACCO EXPORTED FROM THE UNITED STATES.

The following table shows the principal countries to which the American tobacco is exported, but it does not give a correct idea of the ultimate distribution of the tobacco. The amount credited to Germany undoubtedly embraces much that is sent to Austria-Hungary, Switzerland, Africa, and several other countries. The tobacco is sent to Bremen or other German ports and is distributed from there. Unfortunately, there are no reliable statistics as to the actual amount of American tobacco adapted for consumption by these different countries. On the other hand, it is quite likely that the amount credited to the United Kingdom is largely consumed in English territory. In France, Italy, and Spain, where the Regie system prevails, the tobacco is billed direct, and the estimates given undoubtedly represent the quantity of American tobacco consumed in those countries. The Regie system has lately been introduced into Japan, but this has been so recently done that the quantity mentioned in the table has not been in any way affected by the introduction of the system. The trade with Japan has increased very much in the last few years; in 1894 there were 11,084 pounds exported from the United States to that country, while in 1898 the exportation had increased to 2,751,246 pounds. The trade with China has also increased during the same period, but not to such an extent. The amounts credited to Austria-Hungary, Switzerland, and Africa are certainly far below the actual amount of American tobacco used by those countries, for the reason just stated—their distribution from German ports rather than their direct importation from this country.

Average yearly export of leaf tobacco, 1894–1898.

[Compiled from Bulletin No. 16, Section of Foreign Markets, Department of Agriculture.]

Country.	Pounds.	Per cent.	Dollars.	Per cent.
United Kingdom	81,698,086	29.21	8,181,050	34.44
Germany	53,948,979	19.29	4,062,900	17.11
France	30,553,565	10.92	2,419,595	10.19
Italy	26,430,166	9.45	2,495,974	10.51
Belgium	21,278,085	7.61	1,960,958	8.26
Spain	20,770,457	7.43	1,033,192	4.35
Netherlands	19,404,179	6.94	1,154,040	4.86
Canada	11,233,189	4.02	1,093,638	4.60
British Australasia	1,846,830	.66	270,857	1.14
Africa	1,757,846	.63	158,054	.67
Mexico	1,754,181	.63	135,295	.57
Gibraltar	1,351,909	.48	91,296	.38
British West Indies	1,350,355	.48	123,217	.52
Haiti	907,785	.32	102,168	.43
Japan	786,913	.28	54,654	.23
Sweden and Norway	721,438	.26	69,802	.29
Canary Islands	599,054	.21	51,278	.22
British Guiana	580,195	.21	44,301	.19
French West Indies	478,558	.17	38,530	.16
Denmark	176,407	.06	16,805	.07
Austria-Hungary	120,778	.04	10,305	.04
Argentina	104,751	.04	6,386	.03
China	75,426	.03	5,570	.02
Brazil	38,214	.01	4,393	.02
Other countries	1,707,730	.62	166,768	.70
Total	279,675,076	100.00	23,751,026	100.00

ADMINISTRATIVE WORK OF THE FEDERAL GOVERNMENT IN RELATION TO THE ANIMAL INDUSTRY.

By George F. Thompson,
Editorial Clerk, Bureau of Animal Industry.

PRELIMINARY REMARKS.

Diseases of domestic animals have been the subject of many articles and letters which have appeared in the Annual Reports for the Department of Agriculture since its organization, and even previous to that time in the agricultural part of the Patent Office Reports. The first investigations were undertaken by Department authority in 1868, at a time when Texas fever and contagious pleuro-pneumonia were creating considerable alarm among the cattle raisers of the country. In 1882 and 1883 the investigation of Texas fever was taken up with a view to ascertaining its causes and methods of prevention and establishing definitely the areas infected by it. However, no administrative work relative to the animal industry of the country was undertaken by the Federal Government previous to the establishment of the Bureau of Animal Industry in the Department of Agriculture in 1884, except the limited amount done by the Treasury Department at the quarantine stations at the ports of import. One of the purposes of the establishment of the Bureau was to inaugurate and supervise the federal administrative work relative to contagious diseases of animals, and the history of the work in the United States forms a large portion of the history of the Bureau.

The work of the State governments relative to animal diseases can not be given within the limits of this paper, but it is well to say that, even before the Federal Government took up the work, several States had enacted laws for the control of contagious diseases of animals. Such enactments, while they might not have been inefficient, were found to be inadequate, since the regulation of the movement of animals from State to State could only be accomplished by the Federal Government; hence, the necessity was apparent that the latter should take up the great work and cooperate with the States.

AUTHORITY CONFERRED AND SCOPE OF THE WORK.

The authority possessed by the Department of Agriculture for enforcing measures with reference to contagious diseases of domestic animals is conferred by "An act for the establishment of a Bureau of Animal Industry, to prevent the exportation of diseased cattle, and to provide for the suppression and extirpation of pleuro-pneumonia and other contagious diseases among domestic animals," which was approved by the President on May 29, 1884. The power thus conferred is not in all cases sufficient to effect the eradication of a disease, for the reason that the Federal Government can not enforce measures within a State without the legislative consent of that State, unless the animals affected are subjects of or endanger interstate commerce. Its work, therefore, without the cooperation of the States affected, is limited to interstate traffic, and quarantine lines are thus made to follow State lines. It has always been a matter of gratification, however, that wherever the Bureau of Animal Industry has undertaken to suppress and eradicate a contagious disease the authorities of the affected States have readily lent their assistance. A State, on the other hand, can do nothing more than guard its own territory; and, while all of the States have laws for the control of live-stock traffic with a view to the prevention or suppression of disease, it could hardly be expected that they would under all circumstances cooperate with each other effectually. The work of the Federal Government is therefore necessary to the State, and the State laws are necessary to the Federal Government, if success in eradicating disease from the country is to be assured; the federal and State powers are not only supplementary, but interdependent.

CONTAGIOUS PLEURO-PNEUMONIA WORK.

The success of the Bureau of Animal Industry in eradicating contagious pleuro-pneumonia from this country was a triumph that will never be forgotten by the cattle owners of the United States. This disease had become established in several States east of the Allegheny Mountains, and later broke out in Ohio, Illinois, and Kentucky, all great cattle-growing States of the Mississippi Valley. From these States it threatened to spread over the great cattle districts of the West and completely to ruin the industry. The country was thoroughly alarmed, and Congress was prevailed upon to enlarge the powers of the Bureau of Animal Industry to deal with contagious diseases of domestic animals, contagious pleuro-pneumonia being especially mentioned.

A thorough study was immediately begun of the history of the disease in this country and abroad and of the means and methods employed elsewhere for its eradication. Dr. D. E. Salmon, who became the chief of this new Bureau, speaking of this disease in 1883, had said "that the only object kept in view should be its complete extinction by the most summary measures at our command," and further: "We can recommend no temporizing measures with regard to this affection. The only ones applicable are quarantine, restriction of movement of cattle, slaughter of affected animals, and disinfection." The veterinary profession the world over was agreed as to the efficacy of these measures alone, and the Bureau desired to adopt them at once in entering upon the pleuro-pneumonia work. In fact, rules and regulations providing for the destruction by Bureau inspectors of affected animals and the certification of the assessed value of such animals to the Commissioner of Agriculture, who, upon approval, would order payment for the same, were issued by the Commissioner of Agriculture on April 22, 1885; but about the same time the Attorney-General of the United States rendered an opinion, based upon the organic act creating the Bureau, that there are "no provisions for purchasing the diseased and exposed animals," thus rendering null and void the rules and regulations of the Commissioner. However, in the appropriation act for the fiscal year of 1887 the Commissioner was authorized to expend the appropriation "in such manner as he may think best to prevent the spread of pleuro-pneumonia * * * and to expend any part of this sum in the purchase and destruction of diseased animals wherever in his judgment it is essential to prevent the spread of pleuro-pneumonia from one State to another." From that time forward the work was pushed vigorously and successfully.

In accordance with the organic act creating the Bureau and also with the appropriation act just quoted, rules and regulations, dated August 12, 1886, were formulated for prosecuting the work. Provision was made for the acceptance of these rules and regulations by the governors of the affected States, which in most instances was promptly done. In the matter of inspection, the Bureau was to furnish the necessary inspectors, who were to receive from the proper State officers the authority to make inspections of cattle under the laws of the State, to receive such protection and assistance as would be given to State officers engaged in similar work, and be permitted to examine quarantined herds wherever so directed by the Commissioner of Agriculture or the chief of the Bureau of Animal Industry. Reports upon inspections were to be made to the Bureau of Animal Industry and to the proper State authorities. When contagious pleuro-pneumonia was discovered in a herd, the owner or person in charge was at once to notify the inspector, who was to put in force the quarantine regulations of the State in which the herd was located. Every animal of an infected herd was distinctively marked with a lock and chain, which were furnished by the Bureau, but which became the property of the State when placed upon an animal, in order that anyone tampering with them would become amenable to the laws of the State. Quarantine restrictions were for a period of not less than ninety days, and were not to be removed without the consent of the Bureau. All affected and exposed animals were to be slaughtered as soon after discovery as possible, were to be appraised according to the provisions of the State law, and the representatives of the Bureau notified of the appraisement. The Department of Agriculture was to pay to the owner such portion of the appraised value as was provided by the laws of the State for cattle condemned and slaughtered by State authority. All necessary disinfection was to be conducted by the Bureau. The Bureau did not recommend inoculation for the disease, but retained supervision over the herds which were inoculated under State authority.

These regulations were modified from time to time as necessity arose. On April 15, 1887, the chief of the Bureau was authorized to inspect stock yards, cars, boats, and other vehicles of transportation lines, and to make the necessary regulations for their quarantine and disinfection. A few weeks later a notice was sent to the managers of transportation lines, calling their attention to the existence of contagious pleuro-pneumonia among cattle in Illinois, Maryland, and New York, requesting their cooperation in preventing the spread of the disease by means of disinfection and by declining to receive cattle for shipment which were not known to be free from infection. Still later this notice was modified so as to apply to all States affected.

These measures soon began to give good results, enabling the chief of the Bureau of Animal Industry to make the following statement in his report for 1888:

> The prompt eradication of pleuro-pneumonia from Chicago and vicinity is worthy of more than a simple narration of the fact. It may well be considered one of the most important results ever accomplished by the Department of Agriculture. History gives few if any cases where the dairies of a city of the size of Chicago have once been infected with pleuro-pneumonia and where the disease has been eradicated without years of constant work and the expenditure of vast sums of money. Paris was infected more than one hundred years ago, and in spite of the large number of veterinarians in that district, and of the stringent laws and regulations promulgated for its suppression, the disease still exists, and the ravages continue from year to year apparently undiminished.

At the same time the disease was eradicated from all affected districts in Maryland outside of the city of Baltimore, and in Virginia it was completely suppressed. In the other affected States the work had been most satisfactory. In 1889 the progress of the work was notable, being hampered only by lack of full authority on the part of the Bureau properly to enforce its regulations. The plague had not reappeared west of the Allegheny Mountains and no extensions occurred in the Eastern States. Cattle owners and shippers outside of the infected districts had gained such confidence in the work that the presence of the disease in this country no longer interfered with the traffic to any appreciable extent. In 1890 the chief of the Bureau reported as follows:

> The year has passed without any discovery of contagious pleuro-pneumonia outside of the districts which were recognized in the last report as infected. The regulations of the Department have been enforced without difficulty, and the progress of the work for the eradication of this plague has been continuous and rapid.
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> The efficiency of the regulations and of the methods employed under them is demonstrated by the fact that for two years there has not been a case of the

disease outside of the very restricted areas on the Atlantic seaboard which have from the first been recognized as infected. These regulations are still in force, and with the almost complete eradication of the contagion the danger of any infection extending to other sections has practically disappeared.

In 1891 the disease had disappeared from all of the States that had been infected except New Jersey, where it was restricted to a very small area, enabling the Bureau to publish the statement that "the United States is now practically free from contagious pleuro-pneumonia." On March 25, 1892, the last case of the disease disappeared from the United States, and six months later the following proclamation was issued:

PROCLAMATION—ERADICATION OF PLEURO-PNEUMONIA.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF THE SECRETARY.

To all whom it may concern:

Notice is hereby given that the quarantines heretofore existing in the counties of Kings and Queens, State of New York, and the counties of Essex and Hudson, State of New Jersey, for the suppression of contagious pleuro-pneumonia among cattle, are this day removed.

The removal of the aforesaid quarantines completes the dissolving of all quarantines established by this Department in the several sections of the United States for the suppression of the above-named disease.

No case of this disease has occurred in the State of Illinois since December 29, 1887, a period of more than four years and eight months.

No case has occurred in the State of Pennsylvania since September 29, 1888, a period of four years, within a few days.

No case has occurred in the State of Maryland since September 18, 1889, a period of three years.

No case has occurred in the State of New York since April 30, 1891, a period of more than one year and four months.

No case has occurred in the State of New Jersey since March 25, 1892, a period of six months, and no case has occurred in any other portion of the United States within the past five years.

I do therefore hereby officially declare that the United States is free from the disease known as contagious pleuro-pneumonia.

J. M. RUSK, *Secretary.*

Done at the city of Washington, D. C., this 26th day of September, A. D. 1892.

It may be that those countries which are still afflicted with the plague of contagious pleuro-pneumonia are in position better to appreciate the importance of the work done in this country than we are ourselves. If the Bureau of Animal Industry, by eradicating this disease from the country, were to be given credit for the value of all losses which would have resulted from a continuance of the disease, as well as for the money which might have been expended ineffectually by the State authorities toward suppressing it, who can estimate what it would be?

In a summary of the work of the Bureau, published in 1897, the chief wrote as follows regarding the eradication of contagious pleuro-pneumonia:

It is almost impossible at this time to give an idea of the danger with which the cattle industry was menaced by the spread of that fatal and treacherous disease to a point so far in the interior as Chicago or of the difficulties under our form of Government of promptly and effectually meeting the emergency. Fortunately, although the cattle owners in the affected districts were not friendly, the State authorities cooperated in every case and supplied the power which was lacking in federal legislation, and although there were many who questioned the existence of the European lung plague in this country, who did not believe in the success of the measures that were adopted, who were positive that the disease could not be eradicated, or who were certain that untold millions of money would be squandered before the end was reached, the result was accomplished with an expenditure of less than five years of time and of $1,500,000—a sum which is less than 5 per cent of the value of the beef exported in 1892.

When we consider that the Governments of Great Britain, France, and Germany all undertook the work of eradicating pleuro-pneumonia long before the establishment of our Bureau of Animal Industry, and that none of them have yet succeeded in freeing their territory from the plague, we can appreciate the fact that the completion of our task in a comparatively short time was a notable achievement.

In order to make this review of the pleuro-pneumonia work complete and satisfactory, the following tables, taken from the report of the Bureau for 1892, are given:

Work done in the eradication of pleuro-pneumonia, by years.

ILLINOIS.

Character of work.	September 1, 1886, to December 3, 1887.	1888.	Total.
Herds inspected	7,411	140	7,551
Cattle inspected	24,059	285	24,344
Post-mortem examinations	7,267	1,712	8,979
Number diseased on post-mortem	350	4	354
Premises disinfected	677	1	678
Diseased cattle purchased	172	4	176
Exposed cattle purchased	870	129	999

MARYLAND.

Character of work.	1887.	1888.	1889.	1890.	Total.
Herds inspected	5,704	9,809	10,904	4,210	30,627
Cattle inspected	57,868	60,312	79,606	108,376	306,162
Cattle tagged	....	17,749	10,534	5,463	33,746
Post-mortem examinations	2,788	5,820	11,491	12,949	33,048
Number diseased on post-mortem	1,137	507	76	....	1,720
Premises disinfected	145	145	35	1	326
Diseased cattle purchased	a 1,442	459	73	....	1,974
Exposed cattle purchased	a 1,564	1,036	310	20	2,930

a Includes all purchases of cattle from July 1, 1886, to December 31, 1886.

Work done in the eradication of pleuro-pneumonia, by years—Continued.

NEW YORK.

Character of work.	1887.	1888.	1889.	1890.	1891.	a 1892.	Total.
Herds inspected	1,511	12,333	15,861	19,569	13,381	2,537	65,192
Cattle inspected	25,122	99,726	149,396	150,474	136,111	49,925	610,754
Cattle tagged	....	100,370	33,135	33,752	30,294	13,558	211,109
Post-mortem examinations	1,347	15,538	15,375	18,338	26,953	18,871	96,422
Number diseased on post-mortem	447	2,287	1,012	544	31	....	4,321
Premises disinfected	....	1,339	339	434	49	....	2,161
Diseased cattle purchased	266	1,576	1,053	427	25	....	3,347
Exposed cattle purchased	736	3,196	2,819	1,984	284	....	9,019

NEW JERSEY.

Character of work.	1887.	1888.	1889.	1890.	1891.	a 1892.	Total.
Herds inspected	1,428	8,018	8,455	8,492	8,124	16,813	51,330
Cattle inspected	16,461	72,095	76,001	60,659	68,262	128,017	421,495
Cattle tagged	....	13,318	11,672	8,817	12,818	22,153	68,778
Post-mortem examinations	248	6,846	14,242	9,419	4,417	5,562	40,734
Number diseased on post-mortem	113	514	189	43	63	32	954
Premises disinfected	....	275	208	104	57	196	840
Diseased cattle purchased	94	502	116	44	48	40	844
Exposed cattle purchased	117	945	714	242	227	222	2,467

PENNSYLVANIA.

Character of work.	1888.	1889.	1890.	1891.	a 1892.	Total.
Herds inspected	5,291	1,311	1,915	1,096	2,638	12,251
Cattle inspected	72,565	24,003	24,388	55,533	66,487	242,976
Cattle tagged	51,820	1,513	....	....	....	53,333
Post-mortem examinations	13,157	13,412	15,008	55,260	80,384	177,221
Number diseased on post-mortem	72	17	....	....	....	89
Premises disinfected	117	6	....	....	....	123
Diseased cattle purchased	63	....	....	....	....	63
Exposed cattle purchased	131	11	....	....	....	142

SUMMARY.

Character of work.	Illinois.	Maryland.	New York.	New Jersey.	Pennsylvania.	Total.
Total herds inspected	7,551	30,627	65,192	51,330	12,251	166,951
Total cattle inspected	24,344	306,152	610,754	421,495	242,976	1,605,721
Total cattle tagged	....	33,746	211,109	68,778	53,333	366,966
Total post-mortem examinations	8,979	33,048	96,422	40,734	177,221	356,404
Total diseased on post-mortem	354	1,720	4,321	954	89	7,438
Total premises disinfected	678	326	2,161	840	123	4,128
Total diseased cattle purchased	176	1,974	3,347	844	63	b 6,404
Total exposed cattle purchased	999	2,930	9,019	2,467	142	c 15,557

a The figures for 1892 are brought down to September 26, the date on which the quarantine was removed.

b Not including 45 diseased animals purchased in Virginia and District of Columbia.

c Not including 57 exposed animals purchased in Virginia and District of Columbia.