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ECONOMIC BOTANY

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ECONOMIC BOTANY

A Textbook of Useful Plants and Plant Products

BY

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FIRST EDITION

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PREFACE

For some years past there has been an ever-increasing feeling among educators that the average college courses in elementary science have fallen far short of meeting the needs of the average student. For the most part such courses have been conducted on the supposition that their sole purpose was to lay the foundation for further advanced work in their particular field. For the man who knows what he wants, this is essential. Many students, however, fall into other categories. Some take a first course because it is required; others to see whether or not they might become seriously interested in a subject; and still others out of idle curiosity or some less tangible reason. In such cases an elementary course should be so constituted as to be interesting and profitable to the extent of adding to the student's general fund of knowledge even if he does not continue in the field. In other words the course should have more of a cultural than a purely technical value As Gager states it in the preface to his "General Botany," "A subject has cultural value in proportion to the number of human contacts it gives the pupil, the extent to which it broadens his views and extends his interests and sympathies."

The field of applied science, dealing with the practical or economic aspects of a subject, lends itself much better to such treatment than does the field of pure science. This is particularly true of botany. From earliest time plants have been intimately bound up with human existence. Not only have they played an important part in the everyday life of mankind, but they have had a profound influence on the course of history and civilization. A knowledge of the industrial, medicinal, and edible plants cannot fail to broaden one's outlook.

Even though the value of including a considerable amount of economic material in a beginning course in botany may be recognized, the limitations of time or various curriculum requirements usually render such a procedure impracticable. It should be possible, however, to offer at least a half-year course devoted to economic plants as a supplement to the usual first year's

work. Such a course would appeal to students in chemistry, economics, and other fields, as well as to those interested particularly in plant science. Moreover, such a course in economic botany ought to be valuable to the science itself. Botany, more than any other science, has suffered from a lack of interest and appreciation on the part of the average person. Any attempt to educate the layman as to the importance of plants cannot fail to be productive of some beneficial results, and may help in establishing botany on a par with chemistry, physics, geology, and zoology in the eyes of the world.

The present book is the outgrowth of several years' experience in presenting a one-semester course dealing with economic plants. The material utilized is of necessity limited, for the whole field of economic botany is too vast a subject, and only the surface can be scratched. An attempt has been made to include the most important plants of America and other parts of the world insofar as they enter into international commerce. It has not seemed advisable to give the detailed morphology of the various species discussed, or to consider too fully their agricultural and commercial aspects. Such information can be obtained from supplementary readings which should be an integral part of the work of the course. A list of 160 important reference works is appended, and the instructor will find numerous articles available in current magazines, government bulletins, and similar sources. For the benefit of anyone interested in the taxonomic phases of the subject, a systematic list of the species discussed is appended.

Although intended primarily as a textbook, this work should have an appeal to the ordinary reader, since material of too technical a nature has been avoided as far as possible.

The author wishes at this time to express his sincere appreciation of all the assistance that has been granted him during the preparation of the book. He desires especially to thank Professor Oakes Ames, who has read the entire manuscript, for his constant interest and valuable suggestions; Professor Samuel J. Record, F. Tracy Hubbard, and Horace N. Lee, who have criticized various sections; and all others who have in any way contributed with advice and comments. Special thanks are due the staff of the Botanical Museum of Harvard University for their courtesy in placing the facilities of the museum at his disposal and for their friendly cooperation in many ways.

The author is also deeply indebted to many institutions and individuals who have contributed photographs for use as illustrations. In this connection his thanks are due the Bureau of Plant Industry and the Forest Service of the United States Department of Agriculture; the Botanical Museum, the Arnold Arboretum, and the Gray Herbarium of Harvard University, the Massachusetts State College; the University of Maine; the University of Minnesota; the Connecticut Agricultural Experiment Station at New Haven; Breck and Company; the United Fruit Company; E. L. Patch and Company; the United States Beet Sugar Association; the Minute Tapioca Company; and the following individuals: Professor S. J. Record, Professor H. W. Youngken, Professor W. H. Weston, Professor D. H. Linder, Dr. F. M. Dearborn, and Mr. R. E. Schultes

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ALBERT F. HILL.

HARVARD UNIVERSITY,
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ECONOMIC BOTANY

CHAPTER I

THE IMPORTANCE AND NATURE OF PLANT PRODUCTS

THE IMPORTANCE OF PLANTS AND PLANT PRODUCTS TO MANKIND

The average man is likely to consider himself as a being apart from the rest of the organic world, enabled by reason of his superior intellect to lead a self-sufficient and independent existence. He loses sight of the fact, or is ignorant of it, that he is absolutely dependent on other organisms for his very life, and his material happiness as well. His superior intelligence has made him more dependent rather than less so. Although various animal and mineral products contribute to his welfare, it is the plant kingdom that is most essential to man's well-being.

Man's dependence on plants for the essentials of his existence has been of paramount importance in his life since the human race began. Primitive man probably had few needs other than food and a little shelter. Civilization, however, has brought with it an ever-increasing complexity, and has increased man's requirements to an amazing degree. The man of today is no longer content merely to exist, with food and shelter as his only wants. He desires other commodities as well, and raw materials that can be converted into the many useful articles and products which contribute to his enjoyment of life, and which incidentally increase his debt to plants.

The three great necessities of life—food, clothing, and shelter—and a host of other useful products are supplied in great part by plants. An adequate food supply is, and always has been, man's most outstanding need. In the last analysis all his food comes from plants. To be sure he may eat the flesh of animals, but these lower animals are just as dependent on plants as man himself, and they are equally unable to manufacture any of their food from raw materials. Clothing and shelter, the other prime neces-

sities of life, are derived in great part from plant fibers and from wood. Wood is one of the most useful plant commodities in the world today, and it played an even greater role in the past. Aside from its use as a structural material, wood is valuable as a source of paper, rayon, various chemicals, and fuel. Other types of fuel, such as coal and petroleum, make available for man the energy stored up by plants that lived and died ages ago. Drugs, used to cure disease and relieve suffering, are to a great extent plant products. Industry is dependent on plants for many of its raw materials. Cork; tanning materials and dyestuffs; the oils, resins, and gums used in making paints, varnishes, soap, and perfumes; and rubber, one of the most outstanding materials of modern civilization, are but a few of the valuable products obtained from plants.

Aside from their value as sources of food, drugs, and many of the raw materials of industrialism, plants are important to man in many other ways. The role of colorless plants in the economy of nature; the part that bacteria play in disease and many industries; and the effects of forests and other types of natural vegetation in controlling floods and erosion are but a few examples. The aesthetic value of plants has no small influence on man's enjoyment of life, as evidenced by the host of garden enthusiasts and flower lovers.

The production and distribution of plant products have a profound influence on the economic and social life of the nations of the world, affecting both domestic conditions and international relations, and even changing the course of history. It will not be possible within the limits of the present volume to consider the many aspects involved and their fundamental bearing on human affairs and activities. A few examples, however, may be permitted by way of illustration.

The maintenance of an adequate supply of food and raw materials for the use of industry is essential to the existence, as well as the prosperity, of any nation. Few countries are independent in this respect, with the result that foreign trade, with its many ramifications and consequences, plays a necessary and important part in the life of the world. When the population of a country is small, the problems involved are not very great. Most of the civilized nations, however, not only have a large population, but one that is entirely out of proportion to the country's ability to

produce the necessities of life. This tendency to overpopulation in excess of the maximum possible production of food and raw materials is responsible for many of the difficulties and problems that harass the modern world, especially in the case of nations with a restricted land area. The necessity for finding an outlet for their excess population, which all too often is steadily increasing, and the desirability of adding to their domestic supply of commodities have been responsible, in great part, for the policies of aggression that many such countries have pursued in recent years. The story of Japan in Korea and Manchuria and of Italy in Ethiopia and the current increasing demand in Germany for the restoration of her colonies are cases in point.

In recent years various economic problems concerned with agriculture have become increasingly important in the United States, and in other countries as well. These have served to bring home more clearly than ever before the intimate relationship between plants and human welfare.

One of the most serious of these agricultural problems is concerned with overproduction, a condition that has frequently arisen in the history of agriculture. Whenever a large supply of any commodity is available for the market, it usually results in lower prices, which often fall below the figure at which a profit can be realized. A particularly serious case of overproduction had developed in the United States in 1929 when the failure of foreign markets and the low buying power at home combined to cause the piling up of a huge surplus of agricultural products. The lowering of prices which followed created such a great discrepancy between the cost of production and the prices received for the products that the farmers were threatened with wholesale bankruptcy and the welfare of the entire nation was impaired. The efforts of the government to deal with this problem through crop reduction, crop adjustments, and other means are familiar to all. It has been estimated that from 1928 to 1932 some 12,000,000 to 15,000,000 more acres were under cultivation than were necessary to supply all the demands for farm products, both at home and abroad. If this is the case, an obvious method of combating overproduction would be to remove some of these unnecessary acres from cultivation.

Another agricultural problem concerns the proper utilization of the land, and this is related to characteristics inherent in the

plants themselves. The successful pursuit of agriculture in any area depends on the presence of certain environmental factors that are necessary for the particular crop concerned. Each species differs in its soil, moisture, temperature, and other requirements. Satisfactory growth and development can take place only if all these factors are present in proper amounts. This fact has often been ignored and agriculture has been carried on in regions utterly unsuited for crop production, particularly on a commercial scale, with consistently unsatisfactory yields and low financial return as the inevitable result. To remedy this situation, the retirement of these submarginal lands, as they are called, from agriculture has been advocated. This would make possible the utilization of the areas for forests, grazing, wild-life conservation, and human recreation, and at the same time would contribute to crop reduction. The resettlement of some of the farming population, which accompanies the abandonment of agriculture in such areas, obviously has a profound effect on human activities.

Still other agricultural problems are physical, rather than economic, in nature, and are concerned more with productivity than production. The practice of farming necessarily brings about the destruction of the natural vegetation, which has a protective function; this induces conditions that result in the deterioration of the soil. This deterioration may consist of the exhaustion of the mineral nutrients, which is not a serious matter since it can be compensated for by the use of fertilizers, or it may comprise the permanent loss of soil through erosion.

Erosion is caused primarily by the action of water and wind. In the case of water, two types of erosion are produced—sheet erosion and gully erosion. In the former a thin sheet of soil is gradually removed from slightly sloping fields. The process is hardly noticeable and, although widespread, it is not very destructive. Gully erosion, on the other hand, is brought about by the concentrated runoff of water and, where conditions of slope and soil are favorable, results in the formation of deeper and deeper gullies, which eventually render the area unfit for agriculture for all time. Several million acres in the Southern states have been made worthless as the result of this type of erosion. If it is allowed to continue unchecked, its results may be so serious that human life is rendered impossible and barren deserts

are the outcome. This has been the case in many parts of China.

Wind erosion is always more or less active on loose and sandy soil, and it is greatly increased as the result of cultivation and overgrazing, which tend to deplete the moisture-containing humus and pulverize the soil. The growing of cereals, which require constant cultivation, is especially likely to bring about conditions that favor both wind erosion and water erosion. The serious situation that has developed in recent years in the semi-arid regions of the Great Plains is a case in point. Even though the district was unsuited to the purpose, extensive areas of the natural grassland vegetation were plowed up and planted to cereals. The breaking up of the soil and the unusual drought that occurred over a period of several years combined to make conditions exceedingly favorable for wind erosion. This was responsible for the great dust storms that have prevailed in the area and brought widespread destruction in their wake, not only wearing away the soil in some places, but depositing the eroded material on fertile ground elsewhere, thus rendering countless additional acres unfit for agriculture, and perhaps for human habitation for many years to come. It is essential that some sort of soil conservation be put into practice before it is too late. The policies involved in soil conservation include the preservation of soil fertility, the prevention of erosion, the promotion of better land utilization, the stabilization of eroded areas, and various types of crop adjustments.

Plants have been and still are responsible for many of the social ills that beset mankind. In times past the exploitation of workers in various fields of activity concerned with plants has had serious consequences. As examples may be cited slavery, which went hand in hand with the production of cotton in the southern United States; the cruel treatment of the native rubber workers in the Belgian Congo, which shocked the entire civilized world in years past; and more recently the plight of rubber collectors in Brazil.

At the present time the problem of the migratory farm laborer, the share cropper, and the working conditions of farm labor in general are much in evidence.

Perhaps the chief social problem for which plants are responsible is the narcotic drug habit and the illicit trade that has grown

up around it. This constitutes one of the most serious aspects of our modern civilization.

The comments made in the foregoing pages, inadequate though they may be, may perhaps serve to give some idea of the many ways in which plants and plant products affect the welfare of mankind.

THE NATURE OF PLANT PRODUCTS

Before one can fully appreciate the importance of plants, however, some knowledge of their structure and activities is desirable. For plants do not manufacture fibers, gums, resins, starch, sugar, and the countless other materials of use to man from any altruistic motive. Each and every one of these products plays a definite role in the life of the plant itself. Some of them contribute directly to the welfare and maintenance of the plant, while others represent waste products of its various activities.

PROTOPLASM AND ITS ACTIVITIES

The living substance in plants, as in animals, is *protoplasm*, and it is this protoplasm which exhibits the various characteristics that distinguish living matter from nonliving. Protoplasm, for example, has a definite chemical composition peculiar to itself and unlike anything in the inorganic world. It is even more distinctive in its behavior. As a result of the normal activities of the organism the existing protoplasm is continually being used up or worn out. This destructive process is compensated for by a constructive phase in which new protoplasm is built up from raw materials. This dual process of waste and repair is constantly going on during the life of the organism, and constitutes its metabolism. Other manifestations of life which protoplasm possesses are its ability to grow, to reproduce, and to respond to stimuli. Finally protoplasm does not occur in a hit-or-miss manner, but has a definite organization. Every plant and animal consists of one or more infinitesimal units known as *cells* (Fig. 1). These little unit masses of protoplasm are the foundation stones of both the structure of the organism and its functional activities. In one-celled organisms all the vital processes are carried on in the single cell. In the higher plants and animals, where the number of cells is well-nigh countless, a division of labor occurs.

Some cells will carry on one activity, while others will be adapted for different functions.

Cells that are utilized for some particular function are likely to be similar in structure and appearance, and are usually grouped together to constitute what is known as a *tissue*. The plant body comprises many such tissues, each of which carries on some special

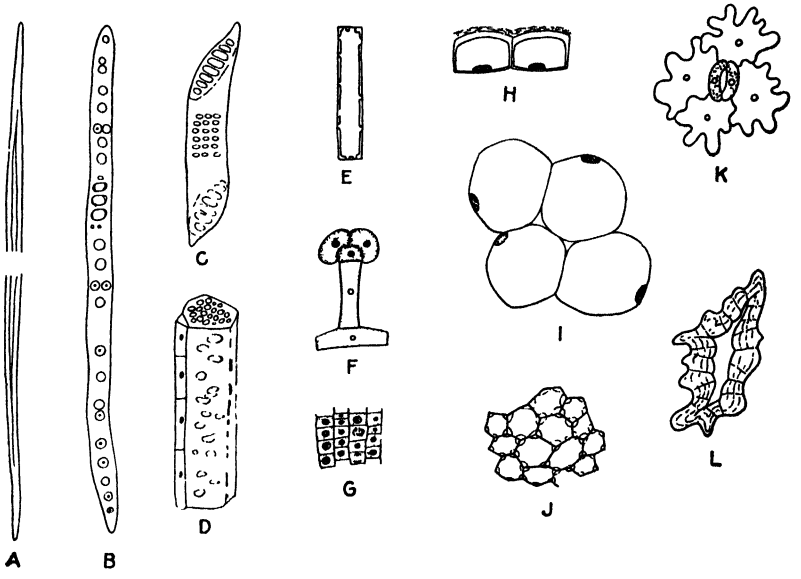


FIG. 1.—Various types of cells *A*, a wood fiber; *B*, a tracheid, *C*, a vessel cell; *D*, a sieve tube with its row of companion cells; *E*, a parenchyma cell from the wood; *F*, a glandular hair, consisting of several cells; *G*, a group of cells from a growing region, *H*, two epidermal cells in section, *I*, four thin-walled parenchyma cells from a storage region; *J*, a group of collenchyma cells; *K*, a stoma with its two guard cells, seen in face view, four adjacent epidermal cells are also shown; *L*, a very thick walled "stone cell" in sclerenchyma. (*Reproduced from Sinnott, Botany: Principles and Problems, McGraw-Hill Book Company, Inc.*)

work. The *organs* of the plant, such as roots, stems, and leaves, are aggregations of tissues so situated that the particular function involved can be carried on to the best advantage.

PHOTOSYNTHESIS

The most significant of these functions in the life of the plant, and for that matter in the life of the whole organic world, is *photosynthesis*. This is the manufacture of food directly from raw materials of the inorganic world. With the exception of a few

bacteria, green plants are the only living things that can actually make food. Animals and colorless plants, which do not have this ability, are in the last analysis absolutely dependent on green plants for their existence. Photosynthesis is carried on, in higher plants, chiefly in the leaves. Using the energy of sunlight, which is put to work through the agency of chlorophyll, the green coloring matter, carbon dioxide and water are combined to produce glucose (grape sugar), with oxygen as a by-product.

The grape sugar formed in photosynthesis is transported to every cell of the plant, and within the cells is used as a source of energy, or is further transformed by various physical and chemical processes into all the substances that play a part in the structure and life of the plant. In other words, the utilization of the photosynthetic sugar constitutes the plant's metabolism. This utilization takes several different forms, but there are five main processes involved: (1) the formation of the cell walls, which constitute the plant skeleton; (2) the manufacture of new protoplasm; (3) the elaboration of various food materials for immediate use or for storage as reserve foods; (4) the production of various secretions and excretions; and (5) the release of energy through the breaking down of the sugar as the result of respiration. We shall consider briefly the various substances formed during the four constructive processes involved in metabolism, indicating their importance to the plant and their usefulness to man.

THE PLANT SKELETON

The vast majority of plant cells are enclosed by a protecting and limiting structure known as the *cell wall*. These walls afford strength and rigidity to the organism, serving as a so[redacted]skeleton. The walls are always composed of *cellulose*, eith[redacted]ne, or in combination with other substances. Cellulose i[redacted]nonliving material elaborated by the plant from grape sugar. Chemically it is a highly complex carbohydrate with the formula $(C_6H_{10}O_5)_n$. The cell walls, like the cells they enclose, are exceedingly variable in size and appearance. Certain types of cells have walls that are very much thickened, and these *sclerenchyma cells*, as they are called, are the most useful for supporting purposes. As the plant body increases in size, more and more support is required and various sclerenchyma tissues are formed, consisting chiefly of *fibers*. Fibers are long pointed cells with very thick walls and

correspondingly small cavities. They tend to interlace and are capable of contracting and stretching. Some fibers, such as the

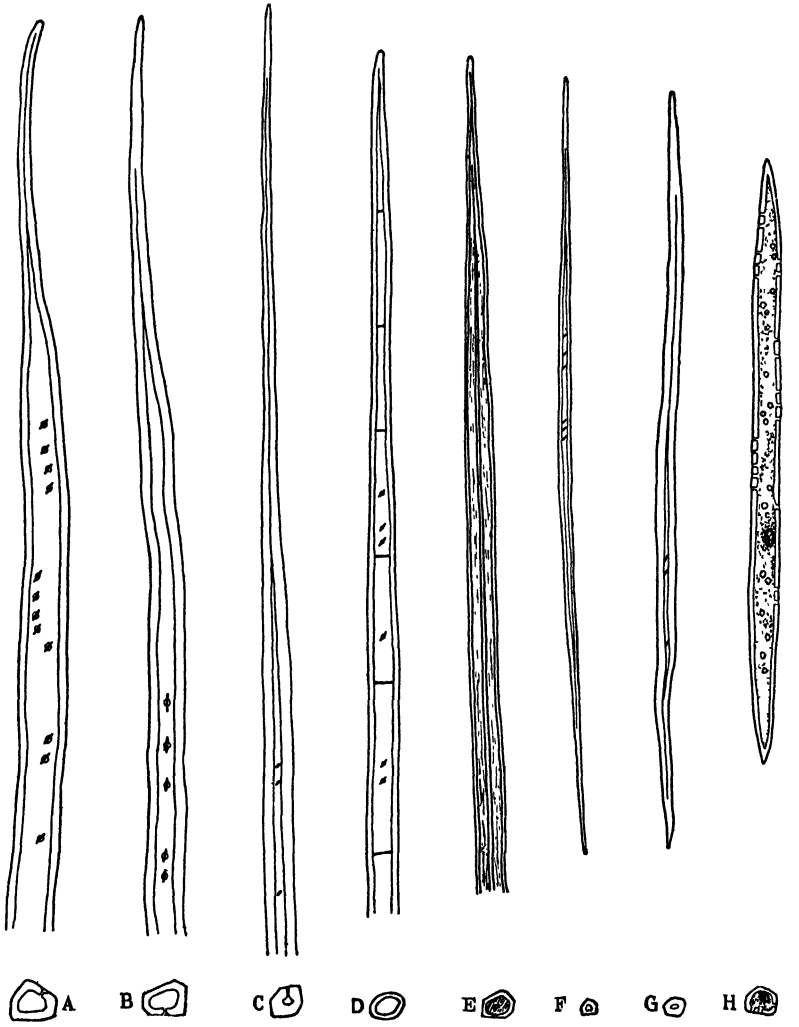


FIG. 2.—Wood fibers. *A*, from *Pyrus Malus; B*, from *Liriodendron Tulipifera, C*, from *Quercus alba; D*, from *Swietenia Mahogani; E*, from *Quercus rubra; F*, from *Carya ovata; G*, from *Guaiacum sanctum; H*, from *Sassafras variifolium.* (*Reproduced from Eames, Introduction to Plant Anatomy, McGraw-Hill Book Company, Inc.*)

hairs on cotton seeds, have walls that are almost pure cellulose. In other cases, as in the bast fibers found in the bark of many

plants, some lignin is present. In the shorter wood fibers (Fig. 2) the walls are almost completely lignified. The presence of lignin greatly increases the strength of a wall without impairing its ability to conduct water. In the parts of a plant where a protective covering is necessary the normal cellulose walls may be infiltrated with waterproofing substances, such as cutin, suberin, or mucilage, all of which, and lignin as well, are manufactured by the plant. In a few instances inorganic materials, silica, for example, may be present in cell walls.

The same properties that make cell walls useful to plants are in many cases responsible for their usefulness to man. Wood, with its lignified walls, has manifold uses wherever a rigid but easily worked material is desirable. The more elastic fibers are the basis of the textile industry and, together with wood, constitute the chief raw materials of the paper industry. Cell walls that contain suberin furnish the cork of commerce. Walls that are nearly pure cellulose are utilized in the manufacture of synthetic fibers, explosives, cellophane, and many other industrial products. Since cellulose and its derivatives are highly combustible, all types of cell walls can be used as fuel. Not only is this true of present-day plants, but those of bygone ages as well. Coal is nothing more than the walls of plants which flourished during the Carboniferous Period of the earth's history and which have gradually lost their gaseous elements. A gradual succession of fuels, showing a progressive loss of hydrogen and oxygen, can be traced from cellulose to lignin, peat, soft coal, and hard coal.

LIVING PROTOPLASM

A considerable part of the sugar manufactured in photosynthesis is used directly in the formation of new protoplasm, to replace any that has broken down, and to provide for the growth of the individual. Protoplasm is a highly complex substance, and its chemical nature is but poorly understood, even though only familiar elements are involved. Among the substances that it contains are simple sugars and more highly elaborated carbohydrates; fats in various stages of synthesis; a large amount of protein material, derived in part from grape sugar and in part from nitrates absorbed from the soil; salts of various inorganic elements, such as iron, phosphorus, magnesium, sulphur, calcium, and potassium; and vitamins, enzymes, and other secretions. Living

protoplasm is naturally of but little use to man, except as he may utilize fresh plant tissues for food. Our present custom of cooking most of our food greatly alters its original nature. It is not at all unlikely that primitive man, who used raw food, derived a greater benefit, owing to the presence of vitamins and the other protoplasmic constituents in an unimpaired condition.

RESERVE FOOD

Plants usually elaborate a much larger amount of food than can be used immediately for building up the plant body, or as a source of energy. This surplus is stored up in highly modified cells in special locations as a reserve supply to be utilized later for growth and other activities. Underground stems, roots, buds, and seeds are the chief storage organs. Three main types of food materials are manufactured by plants, and all three may occur as reserve food. These classes of foods include carbohydrates, fats, and proteins.

Carbohydrates

Carbohydrates are the simplest of the foodstuffs. They are compounds of carbon, hydrogen, and oxygen, in the proportion of two parts of hydrogen to one of oxygen. The principal carbohydrates are sugar, starch, and the various celluloses.

Sugar.—The grape sugar that is manufactured by the plant in photosynthesis is almost universally present in plant cells. This basic material of metabolism, known also as glucose, has the formula $C_6H_{12}O_6$. It is sometimes stored up in large amounts, as in the stems of maize. Fruit sugar, or fructose, another product of photosynthesis, has the same formula, but slightly different properties. It is less common in plants, except in fruits.

The higher, more complex sugars are built up from these simple sugars. The most important of the higher sugars is cane sugar, or sucrose. This substance, which has the formula $C_{12}H_{22}O_{11}$, is accumulated in great quantities in sugar cane and sugar beets, and to a lesser degree in many other plants. All the sugars are soluble in water and so are readily available for use by the plant. They are highly nutritious and constitute a valuable food for the lower animals and man. Man utilizes these sugars, not only as they occur in plant tissues, but by extracting and purifying them as well.

Starch.—The starches are insoluble compounds of a more complex nature with the formula $(C_6H_{10}O_5)_n$. Like the sugars, they are derived from grape sugar, and indeed constitute the first visible product of photosynthesis. Starch is the commonest type of reserve food in green plants and is of the greatest importance in their metabolism Owing to its insoluble nature, how-

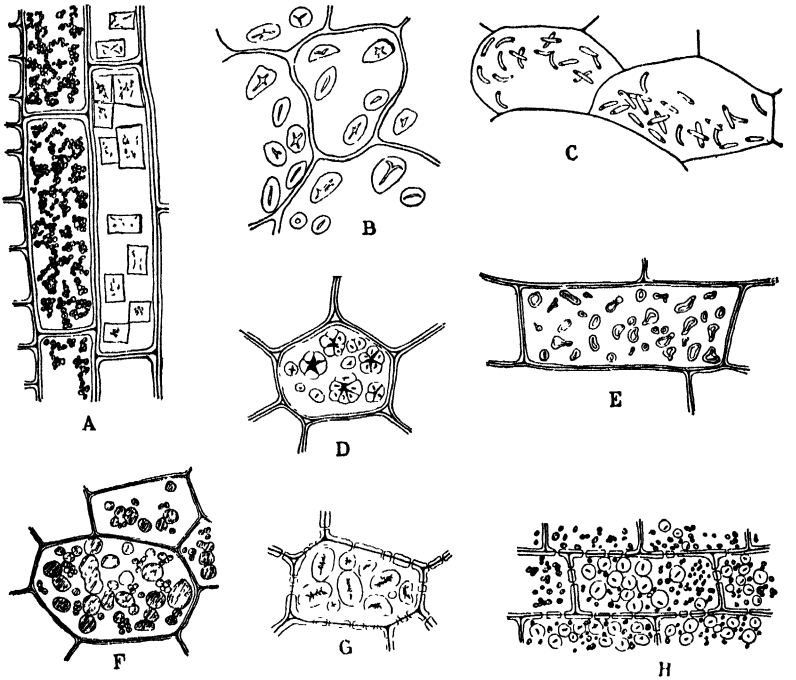


FIG. 3.—Starch grains and tannin. Tannin *A*, in phloem parenchyma of *Pinus* (also crystals); *F*, in pith cells of *Fragaria*, *H*, in ray cells of wood of *Pyrus Malus* (also starch grains). Starch grains: *B*, in pith cells of *Alsophila*, *C*, in outer pericarp of *Musa*; *D*, in cotyledon of *Pisum*; *E*, in ray cell of phloem of *Ailanthus*, *G*, in cotyledon of *Phaseolus*. (*Reproduced from Eames, Introduction to Plant Anatomy, McGraw-Hill Book Company, Inc.*)

ever, starch must be digested, *i.e.*, made soluble, before it can be utilized. This is accomplished through the aid of enzymes that are present in the cells. Starch is stored in large thin-walled cells in the form of distinctive grains (Fig. 3). Man is very dependent on starch, which without question constitutes his most important plant food and plays a part in the industrial world as well.

Cellulose.—Cellulose is the highest type of carbohydrate. We have already noted its presence in cell walls and discussed its function in that connection. It has little, if any, use as a reserve food, although there is some evidence that certain bacteria can make use of it.

Reserve Cellulose.—These substances resemble cellulose physically, but differ in their chemical properties. They include hemicelluloses, pectins, gums, and mucilages. Some of these compounds have a dual role, aiding in the support of the cell walls and serving as reserve food as well. The hemicelluloses may gradually change into pectins, and then into gums.

Hemicellulose.—These substances are often found as extra layers of cell walls, especially in the seeds of tropical plants, such as the date and ivory-nut palm. They are readily digested by plants, but only slightly so by man, and consequently have no food value. They are, however, of some use in the industries.

Pectins.—Pectins or fruit jellies occur in most plant cells, particularly in fruits and vegetables. They are readily soluble in water and can be used as food by both plants and animals. Pectins also increase the water-holding capacity of cells. The middle lamella, the cementing material that holds cell walls together, consists of compounds of pectin. Pectins solidify after they have been extracted from the plant, and man takes advantage of this property in the preparation of jellies and jams.

Gums.—Gums are derived by the breaking down of cellulose or other carbohydrate compounds, and consist of an organic acid in combination with inorganic salts. They may be secreted naturally in the tissues or may arise as the result of wounding. Gums aid in keeping water in the plant, and also serve as a reserve food. Man uses them in the industries, in medicine, and as food.

Mucilages.—Mucilaginous substances, closely related to gums, are widely distributed in the plant world. When moistened with water they do not dissolve, but form a slimy mass. They are secreted in hairs, sacs, or canals. Their function is varied and they may serve as reserve food, as an aid in checking the loss of water or too rapid diffusion, as a mechanism for water storage, and as a means for facilitating seed dispersal. Mucilage is often associated with cellulose in cell walls. Its chief use to man is in medicine.

Fats

Fats, like carbohydrates, are compounds of carbon, hydrogen, and oxygen, but with a very small amount of oxygen. For this reason they are often referred to as hydrocarbons. The formula for triolein, a typical fat, indicates their chemical nature, $C_{57}H_{104}O_6$. Fats are derived from carbohydrates by two processes: (1) the production of fatty acids, (2) the formation of glycerin. These two products unite to form the fats, which are

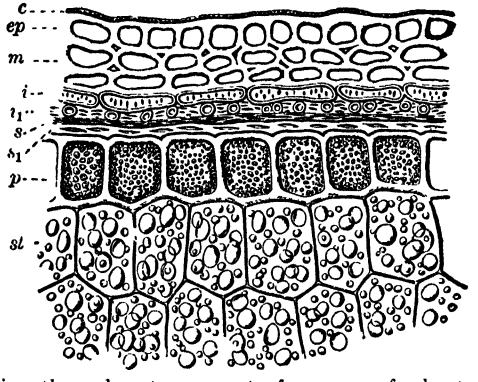


FIG. 4.—Section through exterior part of a grain of wheat *c*, cuticle, *ep*, epidermis; *m*, middle layer of hull, *i*, i_1, layers of hull next to seed coats; *s*, s_1, seed coats; *p*, protein layer with aleurone grains; *st*, cells of endosperm with starch grains. (*After Tschirch, reproduced by permission from Bergen and Davis, Principles of Botany, Ginn and Company*)

either liquid or solid in nature. In the former state fats are usually spoken of as oils, or fatty oils, and occur in the form of small globules. Fats are present in small amounts in all living protoplasm, but are stored up as reserve food chiefly in seeds and fruits. They are insoluble and have to be digested before they can be utilized. Because of their high energy content they are a valuable food for both plants and animals. Fats also are important in medicine and in industry.

Proteins

Proteins constitute the third type of reserve food. They are likewise derived, at least in part, from carbohydrates through the formation of amino acids. These latter simple compounds are then combined with nitrates from the soil, and other substances, to form the highly complex protein molecule. The out-

standing characteristic of proteins is their high nitrogen content. Sulphur is also present, and often phosphorus. A typical protein, gliadin, which occurs in wheat, has the formula $C_{736}H_{1161}N_{184}O_{208}S_3$. Although proteins are the chief constituent of protoplasm, they are stored up for the most part only in seeds, where they occur as solid granules, known as aleurone grains (Fig. 4). Hundreds of proteins have been isolated from plant tissues. After proteins have been changed to a soluble form, they constitute an important food for both plants and animals. They are particularly valuable as muscle and nerve builders, rather than as sources of energy, and as such are an essential part of man's diet. Proteins are never extracted from plant tissues for food purposes. They have no industrial uses.

SECRETIONS AND EXCRETIONS

The various secretions and excretions represent different types of substances that are manufactured by plants; they are very diverse in chemical nature and in function. Some are secreted in special cells or tissues (Fig. 5) for a definite purpose, while others have no apparent use and are merely by-products of metabolism. In many cases, however, these materials are of great value to man, and among them are found some of the most valuable plant products. The most important groups include the essential oils, pigments, tannins, resins, latex, waxes, alkaloids, glucosides, organic acids, enzymes, vitamins, and hormones.

Essential Oils

The essential or volatile oils differ from fatty oils in being highly volatile and aromatic. They are formed in glands or special cells. Their function is apparently to attract insects necessary for pollination by means of their pleasing odors, or to repel hostile insects and animals by their acrid taste. They may have some antiseptic action. Man uses these aromatic oils in the preparation of perfumes and soap and in various other industries, as well as in medicine and as food adjuncts.

Pigments

All the coloring materials that occur in plants are manufactured by the plant itself. These pigments are diverse chemically and functionally. The most important is chlorophyll. This

exceedingly complex substance, with its associated pigments xanthophyll and carotin, is one of the essential factors in photosynthesis. Other colors are of value only as a means of attracting

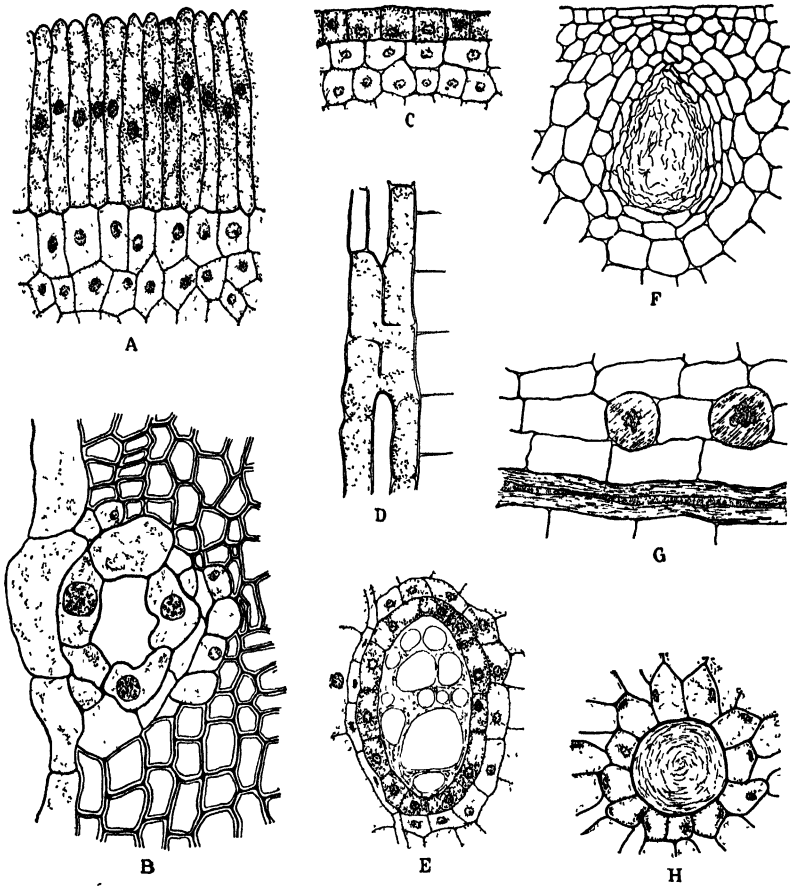


FIG. 5.—Secretory tissue. *A*, nectary of *Euphorbia pulcherrima; B*, resin canal of *Pinus Strobus, C*, floral nectary of *Pyrus Malus, D*, latex vessel of *Tragopogon, E*, oil canal of *Angelica atropurpurea, F*, oil cavity of *Citrus sinensis; G*, latex cells of *Euphorbia splendens, H*, secretory cell of *Liriodendron*. (*Reproduced from Eames, Introduction to Plant Anatomy, McGraw-Hill Book Company, Inc.*)

various insect and other animal agencies of pollination and dispersal, while some are only incidental by-products of the plant's activity. In cases where the pigments are stable, they can be extracted and used as dyes. Formerly natural plant dyestuffs were of great importance in many industries.

Tannins

Tannins are bitter, astringent substances secreted in the bark, wood, or other parts of many plants (Fig. 3). Their function is not fully understood. They aid in the healing of wounds and the prevention of decay and may play a part in the formation of cork and pigments; they also serve as a protection against enemies. Tannins have certain peculiar properties that render them invaluable in certain industries. They have the power of reacting with proteins, such as the gelatin in animal skins, to produce a hard, firm substance. Consequently they are much used in the tanning of leather. They are also able to react with iron salts to produce a black color. This makes them valuable in the dye industry and the manufacture of inks. Tannins are also useful in medicine because of their astringent properties.

Resins

Resins are complex substances probably derived from carbohydrates. They are secreted in glands or canals and are often associated with essential oils and gums. They are formed either naturally or as a result of injury to the tissues. Resins are insoluble in water and so render any surface impervious to moisture. For this reason they play an important role in the paint and varnish industries. In the economy of the plant resins may serve as a waterproofing medium or aid in resisting decay through their antiseptic action. Resinous substances are also used in medicine.

Latex

Many plants secrete a milky or colored juice which is known as latex. This mixture of resins, gums, hydrocarbons, food, and other substances is formed in special cells, or vessels, usually in the bark or leaves. The significance of latex in the economy of the plant is not known. Man, however, obtains rubber, chewing gum, and other valuable products from this material.

Waxes

The surface of leaves and fruits often have a covering of wax secreted by the plant as a protection against excessive loss of

water. This wax is similar to fat in its composition. Waxes are of some slight economic value.

Alkaloids

Alkaloids are vegetable bases containing nitrogen, and they are generally thought to be decomposition products of proteins. They are secreted in special cells or tubes and occur in many different families. Little is known of their biological significance. They may afford protection against enemies because of their bitter taste. Alkaloids are odorless compounds with a marked physiological effect on animals. Consequently they are of the utmost importance in medicine and constitute some of the most valuable drugs. On the other hand, they include some of the most powerful plant poisons and narcotics. Caffeine and theobromine, although they are actually examples of the closely related purine bases, are usually classed as alkaloids and will be so considered in this work.

Glucosides

Glucosides are similar to alkaloids in their properties, but they are derived from carbohydrates rather than proteins. They probably have a protective function as they are usually formed in the bark. It is also thought that they may serve to regulate the acidity and alkalinity of plant cells. Glucosides are useful to man as drugs.

Organic Acids

Organic acids are widely distributed in plants, especially in fruits and vegetables. They may occur in a free state, as salts of calcium, potassium, or sodium, or in combination with alcohols. These fruit acids are probably attractive to animals and so aid in bringing about dispersal of fruits and seeds. They also play a part in metabolism and growth, and in this respect are as important for man as for plants.

Enzymes

Enzymes are universally present in all living organisms, animals as well as plants. There are many kinds, but they usually occur in such small amounts that it is difficult to extract and analyze them. Their function is to act as catalysts. They bring about

all the chemical changes that occur in living matter, without actually entering into the reaction themselves. Perhaps the most important reaction with which they are concerned is digestion, the process by which insoluble substances are broken down into soluble ones and so made available for transportation to all parts of the organism and ultimate utilization. Enzymes are colloidal, and probably protein in nature, and specific in their action. They are concerned not only with oxidation and other destructive phases of metabolism but with the constructive phases as well. They aid in photosynthesis and in the formation of fats and proteins, and are present in every living cell of the plant.

Vitamins

Vitamins are substances which have been discovered comparatively recently and about which little is known. They seem, however, to be absolutely essential for the well-being of both plants and animals. They are formed by plants, and although animals may store them up they are incapable of producing them. Vitamins occur in such small amounts that it is difficult to determine their exact nature, and only a few have been isolated. They are necessary for normal metabolism, growth, development, and reproduction, and, in fact, seem to control most of the constructive phases of metabolism. Vitamins also are necessary for the prevention of various diseases. Fruits, green vegetables, and seeds are important sources of one or another of the vitamins that have been isolated. Seaweeds are particularly valuable for they contain nearly all the known vitamins.

Hormones

Even less is known about plant hormones than about vitamins. Investigations in recent years seem to indicate that one important function is to regulate various growth phenomena. Hormones also play a major part in tropisms, the blooming of flowers, and other activities.

The remainder of this book comprises a discussion of various features concerned with the more important economic plants and plant products that are utilized by man as sources of food, drugs, and the raw materials of industrialism.

The industrial plants, which are perhaps less familiar to the average person, will be considered first, even though they may be less essential to man than the food plants. They include fibers, wood, cork, tanning and dye materials, gums, resins, essential oils, fatty oils, waxes, rubber and other latex products, sugar, starch, and cellulose products. Drugs, together with tobacco and the various narcotics, will be treated secondly. Finally we shall consider the food plants and food adjuncts, which include spices and beverages.

CHAPTER II

FIBERS AND FIBER PLANTS

Plants that yield fibers have without question been second only to food plants in their usefulness to man and their influence on the advancement of civilization. Primitive man in his attempt to obtain the three great necessities of life—food, shelter, and clothing—early turned to plants. Although animal products were available, he needed some form of clothing that was lighter and cooler than skins and hides. For his snares, bowstrings, nets, and the like he needed some form of cordage that was easier to procure than animal sinews and strips of hide. Moreover, some other type of covering for his crude shelters was desirable. All these needs were admirably met by the tough, flexible strands that occurred in the stems, leaves, and roots of many plants.

Almost from the outset plant fibers have had a more extensive use than wool, silk, and other animal fibers. As civilization advanced and man's needs multiplied, the use of these vegetable fibers increased greatly until at the present time they are of enormous importance in our daily life. It is difficult to estimate the number of species of fiber plants, but a conservative figure would be well over a thousand. Seven hundred and fifty occur in the Philippine Islands alone. Fibers of commercial importance are relatively few, the greater number comprising native species used locally by primitive peoples in all parts of the world.

It is a remarkable fact that the most prominent fibers of the present day are of great antiquity. The cultivation of flax, for example, goes back to the Stone Age of Europe, as evidenced by the remains of the Swiss Lake Dwellers. Ancient Egypt was famous for its fine linen. Cotton was the ancient national textile of India, and was used by all the aboriginal nations of the New World as well. Ramie or China grass has been grown in the Orient from time immemorial.

ECONOMIC CLASSIFICATION OF FIBERS

It is possible to classify fibers in six groups, based on their utilization, as follows:

Textile Fibers.—The most important use of fibers at the present time is in connection with the textile industry, which is concerned with the manufacture of fabrics, netting, and cordage. In making fabrics and netting, flexible fibers are twisted together into thread or yarn and then woven, spun, knitted, or otherwise utilized. Fabrics include cloth for wearing apparel, domestic use, awnings, sails, etc., and also coarser materials such as gunny and burlap. The fabric fibers are all of commercial importance. Netting fibers, which are used for lace, hammocks, and all forms of nets, include many of the commercial fabric fibers and a host of native fibers as well. Both commercial and native fibers are used for cordage. For this purpose the individual fibers are twisted together rather than woven. Twine, binder twine, fish lines, rope, hawsers, and cables are among the many kinds of cordage.

Brush Fibers.—These are tough and stiff fibers, or even twigs and small stems, which are utilized in the manufacture of brushes and brooms.

Plaiting and Rough Weaving Fibers.—Plaits are flat, pliable, fibrous strands which are interlaced to make straw hats, sandals, baskets, chair seats, and the like. More elastic strands are roughly woven together for mattings and the thatched roofs of houses, while supple twigs or woody fibers are used for baskets, chairs, and other forms of wickerwork.

Filling Fibers.—These fibers are used in upholstery and for stuffing mattresses, cushions, etc.; for caulking the seams in vessels and in casks and barrels; as stiffening in plaster; and as packing materials.

Natural Fabrics.—These are usually tree basts which are extracted from the bark in layers or sheets and pounded into rough substitutes for cloth or lace.

Paper-making Fibers.—Paper-making fibers include wood fibers, textile fibers utilized in either the raw or manufactured state, and many other kinds.

It is obvious that any one plant cannot be restricted absolutely to any single group in this economic classification, since the same fiber may be used for different purposes and since the plant may yield more than one kind of fiber. Consequently the several species to be discussed will be considered in the group in which they are of the greatest importance.

STRUCTURE AND OCCURRENCE OF FIBERS

Although put to so many different uses, and perhaps differing in texture, strength, chemical composition, and place of origin, with few exceptions fibers are alike in that they are sclerenchyma cells and serve as part of the plant skeleton. For the most part they are long cells with thick walls, correspondingly small cavities, and usually pointed ends. The walls often contain lignin as well as cellulose. Fibers may occur singly or in small groups, but they are more likely to form sheets of tissue with the individual cells overlapping and interlocking.

Fibers may be found in almost any part of the plant—stems, leaves, roots, fruits, and even seeds. The four chief types, classified according to their origin, include bast fibers; wood fibers; sclerenchyma cells associated with the vascular-bundle strands in leaves; and surface fibers, which are hairlike outgrowths on the seeds of various plants. The use of the term "bast fiber" is open to criticism on the ground that it gives no indication as to the particular tissue or region in which the fibers occur. From a morphological viewpoint it would be preferable to designate those fibers which occur in the outer parts of a stem as cortical fibers, pericyclic fibers, or phloem fibers. However, "bast" is a term of such long standing and so firmly established in commerce that it will be used in the present discussion.

Fibers of economic importance are furnished by many different families of plants, particularly those which occur in the tropics. Among the more important may be mentioned the *Gramineae, Palmaceae, Musaceae, Liliaceae, Amaryllidaceae, Urticaceae, Malvaceae, Linaceae, Bombacaceae, Leguminosae, Moraceae, Tiliaceae,* and *Bromeliaceae.*

TEXTILE FIBERS

Textile fibers have certain special requirements. They must be long and must have a high tensile strength, together with cohesiveness and pliability. They must possess a fine, uniform, lustrous staple and must be durable and readily available. A comparatively small number of the multitude of fibers possess these characteristics, and so can be considered as of commercial importance. The chief textile fibers are included in three classes: surface fibers, soft fibers, and hard fibers.

The surface fibers comprise the so-called cottons. The soft fibers are the bast fibers which are obtained chiefly from the pericycle or secondary phloem of the stems of dicotyledons. These bast fibers are capable of subdivision into exceedingly fine flexible strands, and are used for the best grades of fabrics and cordage. They include flax, hemp, jute, and ramie.

The hard or mixed fibers are structural elements found chiefly in the leaves of many tropical monocotyledons, although they may occur in stems and fruits. They are used for the coarser textile products. Sisal, abacá, the agaves, coconut, and pineapple are examples of plants that yield hard fibers.

Surface Fibers

Cotton

Cotton (Fig. 6) is the world's greatest industrial crop, the chief fiber plant, and one of the oldest as well as the cheapest. It was known to the ancient world long before written records were made. References to it are to be found in the works of the Greek and Roman writers. Cotton has been in use in India since 1800 B.C., and from 1500 B.C. to 1500 A.D. that country was the center of the industry. The Hindus were the first people to weave cloth. Cotton was introduced into Europe by the Mohammedans, and the word itself is derived from the Arabic "qutn." Apparently the plant had several origins for Columbus found it in cultivation in the West Indies, and it was known to the Peruvians and Mexicans long before the days of the Spanish conquerors. Cotton was first grown in the United States soon after the first settlements were made. The first cotton mill, however, did not commence operations until 1787.

Production of Cotton.—In 1935–1936 the world produced an estimated total of 26,000,000 bales of cotton, a bale comprising 500 lb. gross weight. The United States led in production with 10,635,000 bales, followed by India with 4,793,000, China with 2,500,000, Russia with 2,250,000, Egypt with 1,750,000, and Brazil with 1,743,000 bales. Brazil has had a spectacular rise as a cotton-producing country during the last few years, the output increasing from 455,000 bales in 1932–1933 to 1,743,000 bales in 1935–1936. For many years prior to 1934 the United States produced at least one-half of the world's output of cotton. Since

that time normal cotton production has been curtailed as a result of governmental regulations. However, an average of about 37,000,000 acres of cotton has been grown in the United States during the last 25 years, nearly one-third of which was

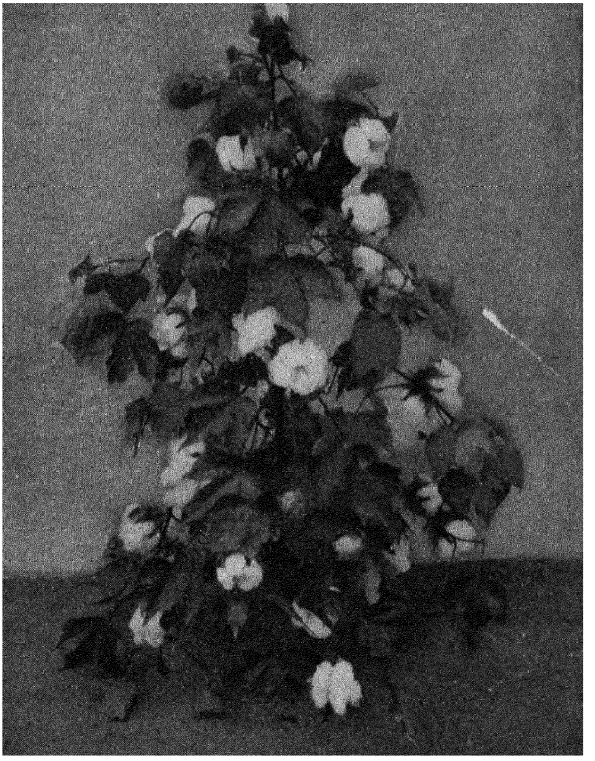


FIG. 6.—A mature cotton plant. (*Reproduced from U.S.D.A. Educational Chart, Index #3, 11, revised, The Cotton Plant.*)

in Texas. The United States, India, Egypt, and Brazil are the chief exporting countries, while Great Britain, Japan, and Germany lead in the importation of cotton.

Characteristics of Cotton.—Cotton is obtained from several species of the genus *Gossypium*. The fine fibrous hairs that occur on the seeds constitute the raw material of the industry. These hairs, which are flattened, twisted, and tubular, compose the lint, floss, or *staple*, the length (Fig. 7) and other qualities of

which vary in different varieties. The cotton plant is naturally a perennial shrub or small tree, but under cultivation it is treated as an annual. It branches freely and grows to a height of 4 to 8 ft. Cotton thrives best in sandy soil in damp, humid regions

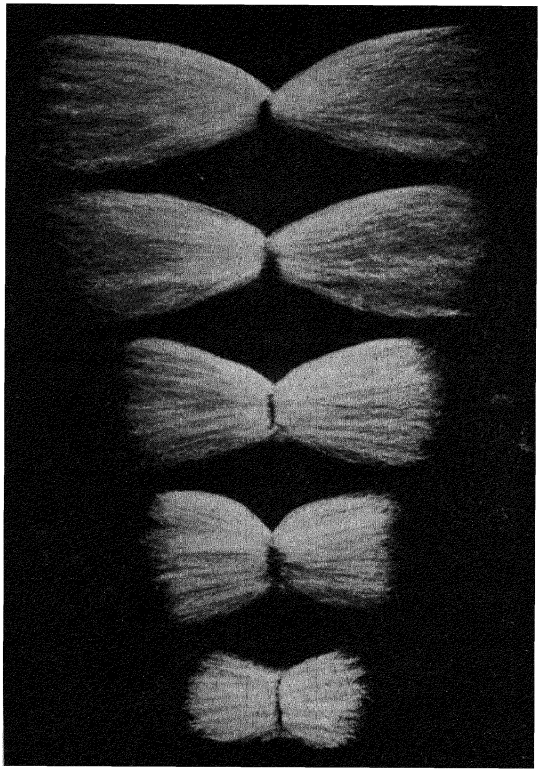


FIG. 7.—Cotton staples. The principal commercial types of cotton showing the variation in length of staples. From top to bottom: sea-island, Egyptian, upland long-staple, upland short-staple, Asiatic. (*Reproduced from U.S.D.A. Yearbook Separate* 877.)

that are near water. This type of environment is especially characteristic of the southern United States and the river valleys of India and Egypt. Cotton matures in five or six months and is ready for picking soon after ripening.

Kinds of Cotton.—The hundreds of varieties of cultivated cotton have been developed from wild ancestors or produced by breeding during the long period of cultivation. These varieties

differ in fiber character as well as other morphological and cultural features. Cotton is a very difficult group to classify, and few authorities agree as to the exact number of species. In the United States, however, the various types are usually referred to one or the other of two species.

1. *Gossypium barbadense.*—The native home of this species is in doubt, but it was probably derived from a Central American plant. In this cotton the flowers are bright yellow with purple spots. The fruit, or boll as it is called, has three valves, and the seeds are fuzzy only at the ends. Two distinct types of cotton belong here:

SEA-ISLAND COTTON.—This type of cotton has never been found growing wild as it was already in cultivation at the time of Columbus. Its light cream-colored fibers are more regular in the number and uniformity of the twists and have a silkier appearance than those of other cottons. These features are exceedingly valuable and sea-island cotton was formerly in great demand for the finest textiles, yarns, and spool cotton, and also for mercerizing. Sea-island cotton was brought to the United States from the West Indies in 1785. The finest types were developed on the islands off the South Carolina coast and the adjacent mainland. Here staples 2 in. or more in length, surpassing all the others in strength and firmness, were produced. Another form of sea-island cotton was grown along the coast in Georgia and Florida, and is still cultivated in the West Indies and South America. This has a staple from 1½ to 1¾ in. in length. The maximum yield of sea-island cotton was only 100,000 bales, but this was compensated for by the greater value of the fiber. In recent years the growing of sea-island cotton has almost entirely ceased owing to the ravages of the boll weevil.

EGYPTIAN COTTON.—Egyptian cotton is grown chiefly in the Nile basin of Egypt, where it was introduced from Central America. By some authorities it is considered to be a derivative of *Gossypium peruvianum*, rather than of *G. barbadense*. The plant is quite similar in appearance to sea-island cotton. The staple, however, is brown in color and somewhat shorter, measuring from 1⅜ to 1¾ in. in length. Because of its length, strength, and firmness this cotton is used for thread, underwear, hosiery, tire fabrics, and fine dress goods. Egyptian cotton was brought

to the United States in 1902 as an experimental crop, and 10 years later it was recommended to farmers in the semiarid regions that are irrigated. A considerable quantity is now grown in California and Arizona. Repeated selection and breeding have resulted in the development of new and better strains, of which Pima is one of the best. A large amount of Egyptian cotton is still imported, amounting at times to one-tenth of Egypt's entire crop.

2. *Gossypium hirsutum.*—This is a native American species long grown by the Incas and Aztecs. It is commonly called upland cotton (Fig. 8). The flowers are white or light yellow and unspotted. The bolls are four- or five-valved, and the seeds are fuzzy all over. Upland cotton grows well under a variety of conditions, but prefers a sandy soil with plenty of moisture during the growing and fruiting season and dryness during the time of boll opening and harvest, together with a temperature range of 60 to 90°F. The northern limit of economic growth is 37°N.L. The great Cotton Belt of the southern United States grows upland cotton almost entirely and produces two-thirds of the world's output of this type of cotton. In general two main types of upland cotton are recognized. These are the *long-staple*, with fibers 1⅛ to 1½ in. in length; and the *short-staple*, with fibers ⅝ to 1 in. long. In both cases the fibers are white. There are over 1200 named varieties of upland cotton, many of which have been developed as a result of breeding experiments. Upland cotton is the easiest and cheapest kind to grow and constitutes 99 per cent of the domestic crop of cotton.

3. *Gossypium herbaceum.*—This third species of cotton is not found in America, but is the chief cotton of Asia. It has been grown in India from time immemorial and is also extensively cultivated for home consumption in Persia, China, Japan, and elsewhere. The staple of Asiatic cotton is short, only ⅜ to ¾ in. in length, but it is strong.

In addition to these cultivated species several wild species of *Gossypium* are still to be found in some tropical and subtropical countries.

The Cotton Industry.—For a long time cotton was a very expensive product for it was difficult to remove the fibers from the seed. The invention of the cotton gin by Eli Whitney in 1793, however, remedied this situation and was responsible for revolutionizing the industry, which rapidly assumed proportions

of first importance in both America and England. Cotton today is probably the most important article in the commerce of the world. The economics of this single crop has a profound effect on both the producing and the consuming nations. The steady decrease in the value of the cotton crop in the United States,

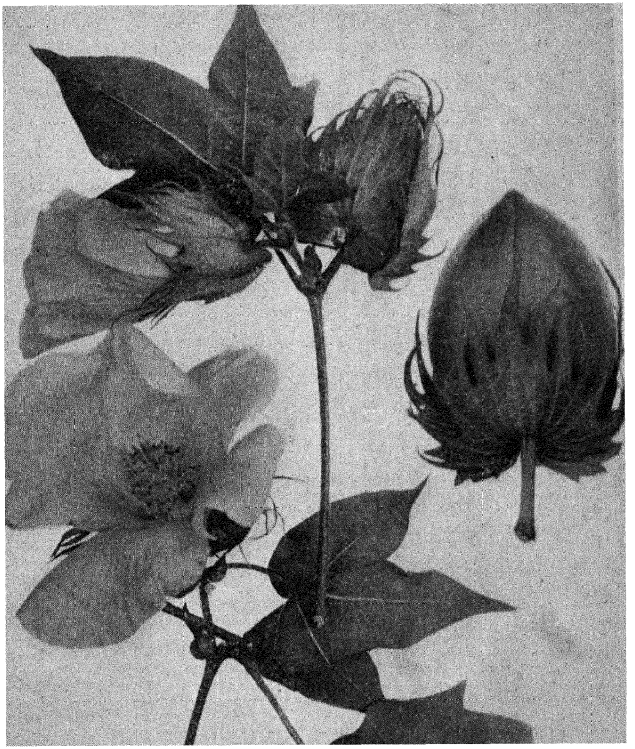


FIG. 8.—Leaves, flowers, and fruit of upland cotton (*Gossypium hirsutum*). (*Reproduced from U.S.D.A. Yearbook*, 1904.)

due to adverse world conditions, has had such a serious effect on the life of the Cotton Belt farmers that government control has been resorted to in recent years in an attempt to improve the situation.

Several operations are necessary in order to prepare the raw cotton fiber, as it comes from the field, for use in the textile industry. In brief these operations are as follows: ginning in either a saw-tooth or a roller gin; baling; transporting to the

mills; picking, a process in which a machine removes any foreign matter and delivers the cotton in a uniform layer; lapping, an operation whereby three layers are combined into one; carding, combing, and drawing, during which the short fibers are extracted and the others are straightened and evenly distributed; and finally twisting the fibers into thread.

The Uses of Cotton.—The chief use of cotton, either alone or in combination with other fibers, is in the manufacture of textiles of all types, which are too numerous to mention. It is an important constituent of rubber-tire fabrics, and unspun cotton is extensively used for stuffing purposes. Absorbent cotton consists of fibers which have been thoroughly cleaned and from which the oily covering layer has been removed. It is almost pure cellulose and constitutes one of the basic raw materials of the various cellulose industries to be discussed later.

One of the most noteworthy advances in the cotton industry has been the utilization of what were formerly treated as waste products. At one time the cotton seed, together with its fuzzy covering of short hairs, or linters, was discarded as valueless. Today, however, all parts of the plant are conserved and yield products that are worth several million dollars annually. The *stalks* contain a fiber that can be used in paper making or for fuel, and the *roots* possess a crude drug. The seeds are of the greatest importance and every portion is utilized. The *linters* furnish wadding; stuffing for pads, cushions, pillows, mattresses, etc.; absorbent cotton; low-grade yarn for twine, ropes, and carpets; and cellulose. The *hulls* are used for stock feed; as fertilizer; for lining oil wells to prevent the caving in of the sides; as a source of xylose, a sugar that can be converted into alcohol, or various explosives and industrial solvents; and for many other purposes. The *kernels* yield one of the most important fatty oils, cottonseed oil, which will be discussed later, and an oil cake and meal which are used for fertilizer, stock feed, flour, and as a dyestuff.

Soft or Bast Fibers

Flax

Flax is second only to cotton as the most valuable and useful of the fibers. It is much superior to cotton in quality and yields a finer fabric. The native home of flax is not known for the

plant has been under cultivation from prehistoric time. It was used by the Swiss Lake Dwellers, the oldest people in Europe who have left remains of their civilization. It was well-known to the Hebrews and is frequently mentioned in the Bible. The Egyptians wore linen and used it for their mummy cloths, and carved pictures of the flax plant on their tombs. Long prior to the Christian era the Greeks imported flax. Five thousand years would be a moderate estimate of the time during which the plant has been under cultivation.



FIG. 9.—Flax (*Linum usitatissimum*), showing the straw spread for dew retting. (*Reproduced from U.S.D.A. Farmers' Bulletin* 669, *Fiber Flax.*)

Flax belongs to the genus *Linum*, which contains several wild species of no economic importance, as well as *L. usitatissimum*, the source of the commercial fiber. The flax plant is an annual herb with blue or white flowers and small leaves, growing to a height of from 1 to 4 ft. The fibers are formed in the pericycle, and consist of very tough, stringy strands from 1 to 3 ft. in length, which are aggregates of many long pointed cells with very thick cellulose walls.

Flax grows best in soil that is rich in moisture and organic matter. It is primarily a crop of temperate regions, although it is grown in other parts of the world to some extent. The preparation of flax is much more laborious than that of cotton, and so is much more costly. The crop is harvested by hand, and

the stems are broken by a process known as rippling. The fibers are then rotted out by submerging the stems in water or by exposing them to dew (Fig. 9). During this process, which is called retting, an enzyme dissolves the calcium pectate of the middle lamella, which holds the cells together, and so frees the fibers. After retting, the straw is dried and cleaned and the fibers are completely separated from the other tissues of the stem by means of an operation known as scutching. Finally the shorter fibers, which constitute the tow, are separated from the longer fibers, which alone can be used in spinning. This is done by hand or by a hackling machine.

Flax fibers are remarkable for their great tensile strength, length of staple, and durability. They are used in the manufacture of linen cloth and thread, canvas, duck, carpets, the strongest twine, the best fish and seine lines, the finest writing paper, and insulating materials.

The Northern European countries are the chief producers of fiber flax. Russia far outstrips the rest of the world, while Poland, the Baltic states, Belgium, Holland, France, and Germany are also important. Flax was introduced into the United States by the Pilgrims, and until 1900 almost every farmer grew enough for his own use. It was a particularly good crop with which to reclaim native soil, and for a long time its cultivation was confined to the frontier areas of the country. At the present time no fiber flax is grown in the United States as a commercial crop. However, in regions where there is little rain, flax is grown for its seed, which is used in medicine and as the source of linseed oil. This valuable industrial fatty oil will be discussed later.

Hemp

There is often considerable confusion as to the real identity of a given commercial hemp fiber, because the term "hemp" is applied rather loosely to include quite a number of very different plants and fibers. The true hemp is *Cannabis sativa*. This plant is a native of Central and Western Asia, but it is extensively cultivated at the present time in both temperate and tropical regions. It often occurs as a troublesome weed.

The hemp plant (Fig. 10) is a stout, bushy, branching annual varying from 5 to 15 ft. in height. It is a dioecious species with

hollow stems and palmate leaves. The best grade of fiber is obtained from the male plants. For its best development hemp requires a mild humid climate and a rich loamy soil with an abundance of humus. Calcareous soils are particularly well adapted to hemp culture.

Hemp fiber is a white bast fiber which develops in the pericycle. It is valuable because of its length, which varies from 3 to 9 ft.,

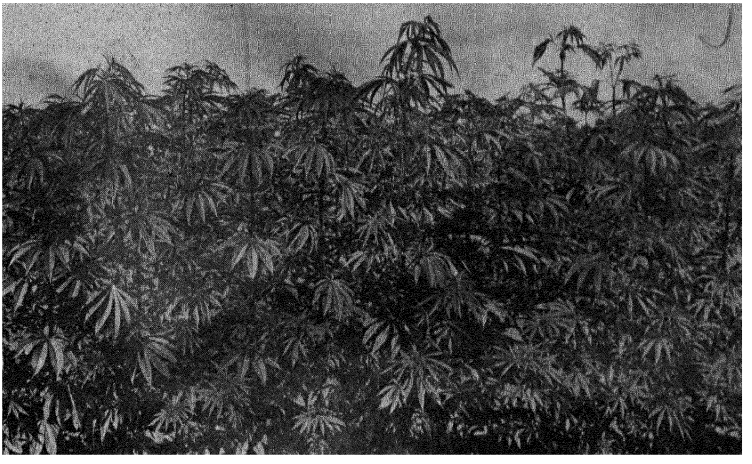


FIG. 10.—Hemp (*Cannabis sativa*). A field about two months after planting. Hemp is the source of a textile fiber, a drying oil, and a narcotic drug.

its strength, and great durability. It lacks, however, the flexibility and elasticity of flax, because it is somewhat lignified. The yield of hemp is large, an acre producing 2 or 3 tons of stems, 25 per cent of which is fibrous material. The plants are harvested by hand or machine and are shocked and dried. The fibers are separated from the rest of the bark by retting, either in dew or in water. They are then broken, scutched, and hackled by hand. Hemp must be harvested when the male flowers are fully out; otherwise the fibers are too weak or too brittle to be of value.

Hemp is a very old crop and has been grown in China for centuries. It was introduced into Europe about 1500 B.C., and that continent is the center of the industry today. Hemp has been grown in the United States since 1775 and at one time

constituted a considerable industry in Kentucky. At the present time Wisconsin leads in production. It is an expensive crop, however, and in most regions has been gradually replaced by other coarse fibers.

Hemp is used for ropes, twine, carpets, sailcloth, yacht cordage, binder twine, sacks, bags, and webbing. Hemp waste and the woody fibers of the stem are sometimes used in making paper. The finer grades of hemp can be woven into a cloth that looks like coarse linen. The short fibers, or *tow*, and ravelings constitute *oakum*. This is used for caulking the seams between the planks used in shipbuilding; in cooperage; and as a packing for pumps, engines, etc. In tropical regions hemp is grown for its seed, and also for a drug that is obtained from the flowering tops and leaves. The seeds contain an oil that is useful in the soap and paint industries as a substitute for linseed oil. The drug, known as hashish, is a resinous substance that contains several powerful alkaloids. Its use and the important part it has played in the economic and social life of many countries will be discussed later.

Jute

Jute is probably used more extensively than any other fiber except cotton, although it is much less valuable than either cotton or flax. Jute is a bast fiber obtained from the secondary phloem of two species of *Corchorus*, an Asiatic genus. The best fiber comes from *Corchorus capsularis*, which is grown in upland areas, but that from *C. olitorius*, a lowland species, is but little inferior, and the two are not differentiated for commercial purposes. Although probably a native of Malaya or Ceylon, jute is now almost entirely an Indian crop. Several million acres are cultivated in the valleys of the Ganges and Brahmaputra rivers. Jute is a tall, slender, half-shrubby annual (Fig. 11) with yellow flowers. It grows to a height of 8 to 12 ft. It requires a warm humid climate and a rich, loamy, alluvial soil, which is frequently inundated.

The crop is harvested within three or four months after planting, while the flowers are still in bloom. The stems are retted in pools or tanks for a few days to rot out the softer tissues, and the jute, or *gunny*, strands are then loosened by whipping the stems on the surface of the water. The very long fibers are quite

before they can be used. They constitute the China grass, or "filasse," which is extensively used in the manufacture of grass cloth and other dress goods in Asia. Ramie is used in Europe for underwear, portieres, upholstery, thread, and paper Although it is the strongest fiber known, being three times as strong as hemp, ramie is not very generally used because the treatment necessary to remove the fibers is so expensive. The fibers also lack flexibility and are too smooth for good cohesion. A process has recently been developed by which a fiber is obtained which has met all the tests and requirements of the textile manufacturers, and for which a multitude of uses is predicted.

A variety of ramie, *Boehmeria nivea* var *tenacissima*, is sometimes differentiated as **rhea.** This plant, a native of Malaya, resembles ramie except that the leaves are green on both sides. For commercial purposes rhea fiber is included under ramie.

Sunn Hemp

Sunn, sun, or san hemp (*Crotalaria juncea)* is an important Asiatic fiber plant. It is not known in the wild state for it has been cultivated for centuries. In fact, it is the earliest fiber to be mentioned in Sanskrit writings. The plant is a shrubby annual from 6 to 10 ft. in height, with bright yellow flowers. It is extensively grown in India where over 500,000 acres are planted every rainy season, chiefly in the region around Madras. Sunn hemp is also cultivated in Ceylon and elsewhere in the Orient. The bast yields a fiber that is stronger than jute, lighter in color, and more enduring. It is used for cordage, sacks, nets, and coarse canvas. The United States imports a considerable quantity for coarse twines.

Other Soft Fibers

Nearly all the members of the *Malvaceae* yield bast fibers that can be used for textile purposes. Some of these are of considerable commercial importance. Among them may be mentioned:

China Jute or Indian Mallow (*Abutilon Avicennae*).—This annual plant yields a strong, coarse, grayish-white, lustrous fiber with the same general characteristics and uses as jute. It is extensively grown in China, and has been introduced into the United States where it thrives well. In many places it has

become a troublesome weed. The fibers take dyes readily and are much used in China in rug making.

Deccan, Ambari, or Gambo Hemp (*Hibiscus cannabinus*).—This species, a native shrub of the East Indies, is extensively grown in Nigeria, India, and some other countries for its fiber. This is used as a substitute for hemp and jute in making cordage and coarse canvas. A considerable amount is exported to Great Britain.

Roselle or Rama (*Hibiscus Sabdariffa*).—This African species has been introduced into the Philippine Islands and other tropical countries. It grows very rapidly and yields a strong silky light-brown fiber. This is a good substitute for jute in both the textile and paper industries.

Aramina (*Urena lobata*).—This species occurs as a weed in all tropical countries. It furnishes a yellowish-white fiber that is more lasting than jute and is used as a substitute in many industries. It is grown commercially in Cuba, Madagascar, and Brazil, where its chief use is in making coffee sacks.

Other malvaceous species yielding fibers of minor importance include **okra** (*Hibiscus esculentus*), **majagua** (*H. tiliaceus*), and **Cuba jute** (*Sida rhombifolia*).

The American Indians used the bast fibers of many plants for their bowstrings, nets, and similar purposes. The Colorado River hemp (*Sesbania exaltata*) was extensively used by the western tribes, while the Indian hemp (*Apocynum cannabinum*) yielded the fiber of greatest importance to the eastern Indians.

Hard or Structural Fibers

Abacá or Manila Hemp

This important fiber of unusual excellence is obtained from the sheathing leaf stalks, which form the apparent trunk, of several species of wild plantain or banana. *Musa textilis* (Fig. 13) is the most important source. This plant resembles the true banana, but has narrower, more tufted leaves and inedible fruits. Although this species is found from India to the Philippine Islands, it is only in the latter region that it is of commercial importance. The fibers vary in color from white to reddish yellow, and are very light, stiff, and lustrous (Fig. 14). They represent structural elements, sclerenchyma cells, and are

removed from the leaves by hand—a slow and laborious process. The fibers vary from 6 to 12 in. in length. They are the most elastic and among the strongest known. The chief use of abacá is in the manufacture of cordage, especially marine cables, for the fiber is not injured by salt or fresh water. Binder twine,



FIG. 13.—A plantation of abacá or Manila hemp (*Musa textilis*) in the Philippine Islands.

bagging, papier mâché, wrapping paper, hats, and a lustrous cloth known as sinamay cloth are also made from this fiber. Abacá is the chief crop of the Philippine Islands. Normally over 200,000 tons are produced annually, which make up three-quarters of the total exports from the islands. The plants are grown everywhere, for they require only a rich, moist, well-drained soil and a warm humid climate.

Agave Fibers

Agave fibers rank next to cotton in importance in America, their trade value amounting in good years to over $35,000,000. The agaves are stemless perennials with basal rosettes of erect fleshy leaves. These leaves contain the fibers, which are removed by hand or machine. The numerous species are of rather local occurrence. They are very drought-resistant and are adapted to dry sterile soils. Several kinds are of commercial importance. Owing to the fact that the trade names for the different agave



FIG. 14.—Abacá fiber in bundles as it is taken from the plantation to the market in the Philippine Islands.

fibers tend to intergrade, considerable confusion exists as to the identity of the species concerned. The chief types include:

Henequen or Yucatan Sisal (*Agave fourcroydes*).—This native Mexican species was long used by the Aztecs. At the present time it is grown chiefly in Tampico (Fig. 15). The leaves bear spines, which make them difficult to handle. The fiber, which is scraped out from the leaf tissue, is light straw colored. It is hard, wiry, and elastic, measuring from 3 to 5 ft. in length. Henequen is used chiefly for binder twine, lariats, and similar products. It is not suitable for marine or hoisting cables as it is too heavy and too weak.

Sisal (*Agave sisalana*).—Sisal is very similar in appearance to henequen but lacks the spines on the leaves. A native species of Mexico and Central America, it is now cultivated in Hawaii, the East and West Indies, and many sections of Africa, especially the British possessions. The plant is exceedingly drought-resistant and will grow where all other species fail. Little or no cultivation is necessary. The coarse, stiff, light-yellow to white fibers are removed from the leaves by hand or by means of a

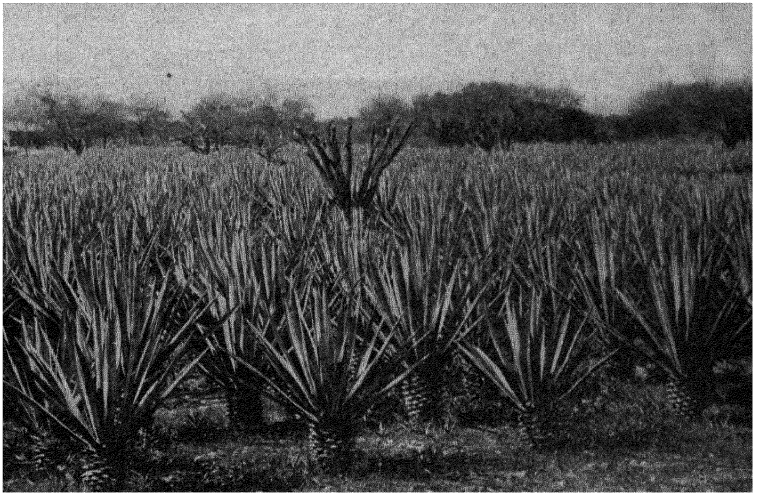


FIG. 15.—Henequen (*Agave fourcroydes*). A field near Victoria, Tamaulipas, Mexico, from which two crops of leaves have been cut The plants are six years old.

"raspador." They are cleaned, dried, and packed in 600-lb. bales for shipment. The United States uses a large amount of sisal for binder twine, most of the supply coming from Mexico and the Dutch East Indies.

Istle.—Several fibers have been used in Mexico from prehistoric times under the names istle, ixtle, or Tampico fiber. Usually three kinds of istle are now recognized: jaumave istle from *Agave heteracantha*, tula istle from *A. Lecheguilla*, and palma istle from various species of *Yucca*. The fibers are obtained from immature leaves, and, although shorter than those of sisal and henequen, they are very strong and durable. Because of their stiffness and harshness they were formerly used for brushes, but

now they serve as cheap substitutes for sisal and abacá. Ore sacks made of istle have been known to last 10 years.

Maguey.—The true maguey (*Agave Cantala*) is an Asiatic species found in India, Java, and other countries. It is grown on a commercial scale in the Philippine Islands as a substitute for sisal. Mexican maguey is obtained from several different species of *Agave*. These fibers are of little commercial importance. The plants, however, are of considerable interest for their juice is used in making the Mexican beverages, pulque and mescal.

Mauritius Hemp

Mauritius hemp is obtained from the leaves of the green aloe (*Furcraea gigantea*). This species is a native of tropical America, but is now widely distributed throughout the tropics of both hemispheres, where its fiber is used for domestic purposes. It is grown for commercial use only in the islands of Mauritius and Saint Helena. The plant resembles an agave in habit, but has less rigid leaves and a very tall peduncle or flowering stalk. This "pole," as it is called, reaches a height of from 20 to 40 ft. and is the longest known. The fibers are exceedingly long, white, soft, and elastic. They are weaker than sisal. They are used alone or in mixture for making hammocks, bags, coarse twine, and other small cordage.

Cuban hemp, a similar fiber, is obtained from *Furcraea hexapetala*.

New Zealand Hemp

This fiber comes from the leaves of the irislike *Phormium tenax* (Fig. 16). This plant is a native of the swampy regions of New Zealand but it is now found throughout the tropics, and even in temperate regions. It has been introduced into the United States chiefly as an ornamental plant, although it is grown for its fiber in California. New Zealand hemp is the only important hard-fiber plant of temperate countries. The fibers are softer and more flexible than abacá and have a high luster. They are used chiefly for mattings, tow lines, and other forms of cordage, and to some extent for cloth.

Bowstring Hemp

Numerous species of the genus *Sansevieria* occur as wild plants in various parts of tropical Africa and Asia. These bowstring hemps are herbaceous perennials with basal rosettes of swordlike leaves arising from a creeping rootstalk. The leaves yield a strong white elastic fiber, which has long been used by the native peoples for mats, hammocks, bowstrings, and other types of

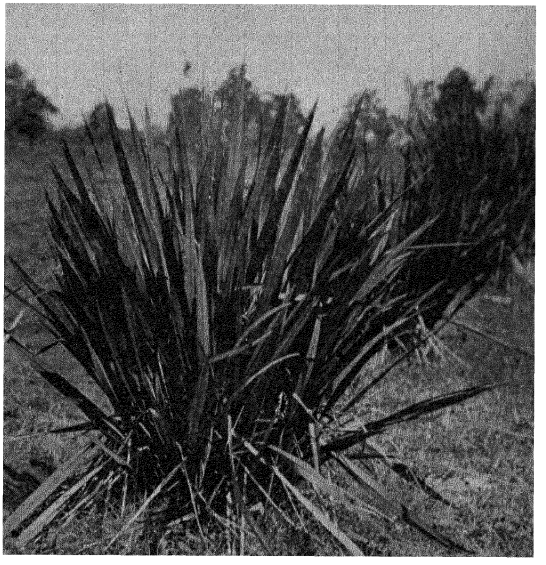


FIG. 16.—New Zealand hemp (*Phormium tenax*). This plant is cultivated in California for the fiber. It is also grown for ornamental purposes.

crude cordage. Wild plants are usually utilized, but some species are cultivated. The Hindus have grown bowstring hemp for a long time. The fibers are removed by hand or by mechanical means. Important species include *S. thyrsiflora* of tropical Africa, grown also in Jamaica and Central America; *S. Roxburghiana* of India; and *S. zeylanica*, cultivated in Ceylon and many other tropical countries. A few species have been introduced into the United States, prominent among which is the Florida bowstring hemp (*S. longifolia*).

Coir

Coir is the term applied to the short, coarse, rough fibers (Fig. 17) which make up the greater part of the husk of the fruits of the coconut palm (*Cocos nucifera*). Coir is the only prominent fiber that is obtained from fruits. Unripe coconuts are soaked in salt water for several months to loosen the fibers. They are

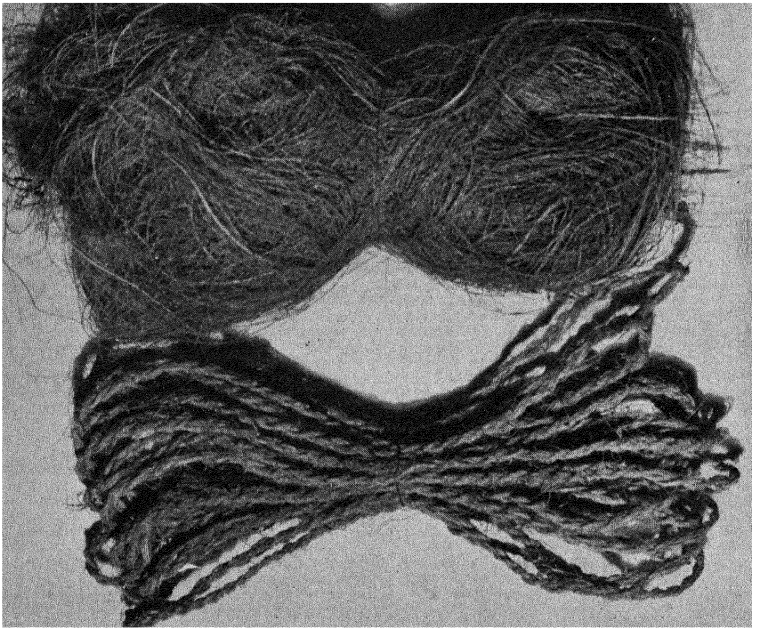


FIG. 17.—*Above*, coir, the coarse fibers from the husk of the coconut (*Cocos nucifera*); *below*, sennit, the rope that is made from it. Sennit is the most universally used type of cordage in the South Seas. (*Courtesy of the Botanical Museum of Harvard University.*)

then beaten to separate the fibers, which are then washed and dried. The uses of coir are varied. In tropical Asia and the South Seas it is the source of sennit braid, which is used for hawsers, cables, and small cordage. Coconut fibers are superior to all others for this purpose for they are very light and elastic, and exceedingly resistant to water. Coir is also used for doormats, floor coverings, coarse textiles, upholstery, stuffing for the bearings of railroad cars, and as a substitute for oakum.

Pineapple

The leaves of the pineapple (*Ananas comosus*), the source of the familiar tropical fruit, furnish fibers of great strength and fine qualities. They are shiny white, very durable and flexible, and are not injured by water. When grown for the fiber, pineapples are planted closer together and develop longer leaves To be of value the fibers must be taken from leaves that have not attained their maximum growth. Usually two-year old leaves are cut and the fibers scraped out by hand, a delicate and expensive process. After being dried and combed out, the fibers are tied end to end and can then be woven. In the Philippine Islands piña cloth, one of the most delicate and costly of fabrics, is made from these fibers. Formosa and China also utilize pineapple fiber in making strong fabrics.

BRUSH FIBERS

An important use of vegetable fibers is in the manufacture of brushes, brooms, and whisks Such fibers must be very strong and elastic. In some cases whole twigs, fine stems, or roots are utilized; in others the fibers are obtained from leaf stalks Among the more important brush fibers may be mentioned.

Piassava

Several species of palms growing in tropical America and Africa are the source of the brush fibers that are known commercially as piassava, piassaba, or bass. These trees have leaf stalks or leaf sheaths which yield the stiff, coarse, brown or black fibers used in making brushes for street sweeping

West African piassava is obtained from the wine palm (*Raphia vinifera*), an exceedingly abundant species in the tidal bayous and creeks of Liberia and other countries on the west coast of Africa. The leaf stalks are retted and the bundles beaten out. The long fibers are used for mats as well as brushes. A wine is made from the sap of this palm.

Brazilian piassava comes from two species of palm found everywhere in the lowlands of the Amazon and Orinoco regions. Bahia piassava comes from *Attalea funifera*. In this species the stiff, wiry, brown fibers are almost bristlelike. They are removed from the swollen bases of the leaf stalks with an ax. Their chief use is for the brushes of street-sweeping machines

and for coarse cables. Para piassava fibers are produced on the margins of the leaf petioles of *Leopoldinia Piassaba*. They are used for brushes and brooms, and also for ropes and baskets by the natives.

Several other coarse fibers, such as palmyra and kittul fiber, are classed as piassava in the trade. **Palmyra fiber** is obtained from the Palmyra palm (*Borassus flabellifer*) of the East Indies. This

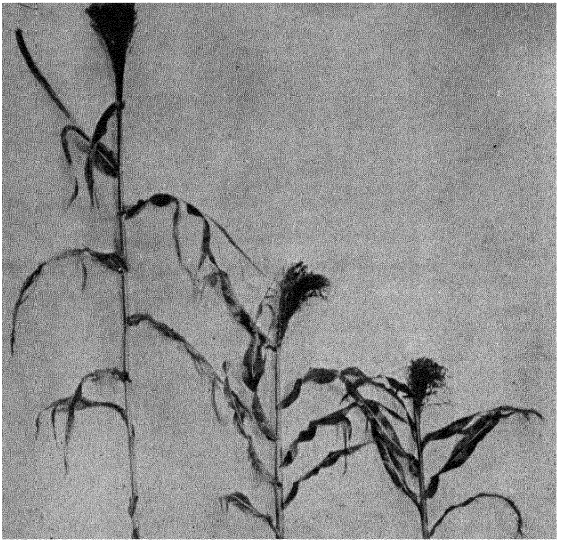


FIG. 18.—Broomcorn plants (*Sorghum vulgare* var. *technicum*), showing the comparative height of the varieties. From left to right: standard, dwarf standard, and dwarf.

species is one of the most useful of the palms, all parts of the plant being used for some purpose or other. The fibers are made up into rope, twine, paper, and machine brushes. **Kittul fiber** is finer, softer, and more pliable. It comes from the leaf sheaths of the toddy palm (*Caryota urens*) of Ceylon and the East Indies. The black bristles are made into ropes of great strength and durability or into soft brushes, and also serve as substitutes for horsehair and oakum.

Broomcorn

Broomcorn is a variety of sorghum (*Sorghum vulgare* var. *technicum*). It differs from the other sorghums in having a

panicle with long straight branches. This inflorescence, or seed head, is the "brush," the valuable part of the plant. Standard and dwarf forms are recognized (Fig. 18). The brush of the former is stronger and is used for carpet brooms; that of the latter

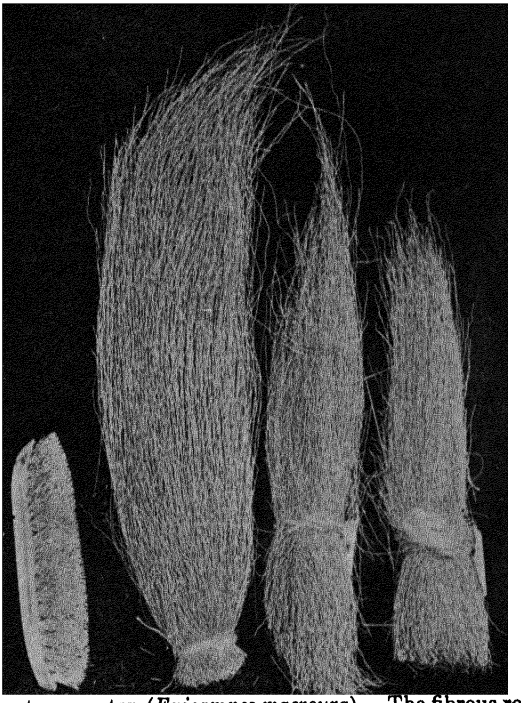


FIG. 19.—Broomroot or zacaton (*Epicampes macroura*). The fibrous roots of this plant are used in the manufacture of brushes.

type is used for whisk brooms. In the United States broomcorn is grown chiefly in the Mississippi valley. It is harvested before the flowering season is over by cutting the stems a few inches below the head. The heads are then sorted, threshed, and dried.

Broomroot

Broomroot or zacaton (*Epicampes macroura*) is extensively used in the manufacture of the cheaper brushes. The plant is a grass, found from Texas to Central America, particularly in the mountainous regions of Mexico. It is a perennial species with

tufted wiry culms and coarse roots. As the name indicates, the roots are the part utilized (Fig. 19). These are dug up at all seasons of the year by the peons. After washing, cleaning, and drying, the roots are cut from the tops, graded according to quality, length, and color, and baled for shipment.

PLAITING AND ROUGH WEAVING FIBERS

Only a few of the materials used for plaited or coarsely woven articles are of commercial importance, the greater number being used in native manufactures. The raw materials comprise the stems of reeds, rushes, grasses, willows, bamboo, rattan, and many other plants, as well as the leaves and roots. These materials are used entire or split. They are woven or twisted together in the simplest manner and made up into hats, sandals, mats and matting, screens, chair seats, baskets, and similar articles.

Hat Fibers

In many parts of the Orient and in Europe, wheat, rice, barley, and rye are grown for the purpose of making braids or straw plaits for hats. The plants are grown close together so they will have few leaves, and they are harvested before maturity. The stems are split lengthwise before plaiting. The Leghorn and Tuscan hats of Italy are among the best known of the straw hats.

Carludovica palmata, a stemless palm of tropical America, is the only source of Panama hats. This species, which grows wild in humid forests, is also cultivated extensively in parts of Colombia and Ecuador. Young leaves are collected by the natives, split into thin pieces, cleaned, bleached, and woven by hand. About six leaves are required to make one hat. The so-called Puerto Rican hats are made from the leaves of the hat palm (*Sabal causiarum*).

Mats and Matting

Commercial mattings are made in many of the Eastern countries from various sedges, rushes, and grasses. Usually the stalks or leaves of these plants are used alone, but they may be combined with a warp of cotton or hemp. Among the princi-

pal species utilized may be mentioned the Chinese mat grass (*Cyperus tegetiformis*) (Fig. 20) and the Japanese mat rush (*Juncus effusus*). The United States imports several million dollars' worth of these products annually.

Native mats are made from a great variety of plants. Perhaps the most outstanding source, particularly in Southeastern Asia and Oceania, is the screw pine (*Pandanus tectorius*). *P. utilis*

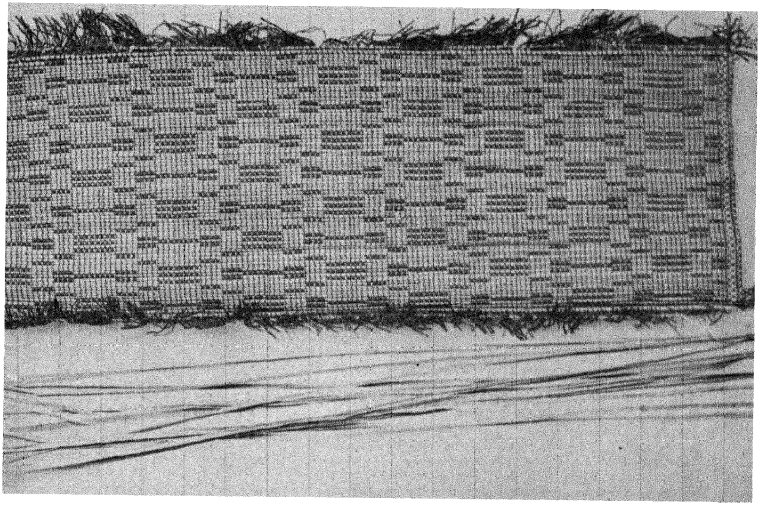


FIG. 20.—Chinese mat grass (*Cyperus tegetiformis*), showing a piece of matting and the raw material from which it was woven.

is also important. The leaves of these shrubby plants are also used for sugar bags, cordage, hats, and thatching.

Baskets

The manufacture of baskets from fibers or fibrous materials is an industry belonging to both civilized and native peoples. The various species utilized are too numerous to mention. Roots, stems, leaves, and even woody splints are used. Commercial baskets are usually made from rushes, cereal straw, osiers or willows, and ash or white oak splints. Sweet-grass baskets, made from *Hierochloë odorata*, a common species in swamps along the coast and the Great Lakes, are a familiar sight in eastern North America. Another important source of basket material

is the raffia palm (*Raffia pedunculata*), a tree indigeneous to Madagascar. Strips of the lower epidermis of the leaves of this palm constitute the raffia of commerce. This fiber is so soft

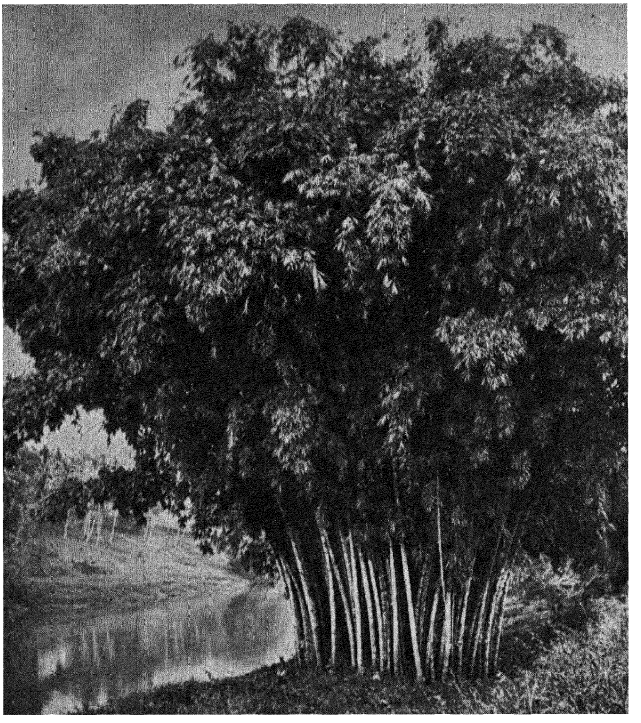


FIG. 21.—A clump of giant bamboo (*Dendrocalamus*) in Ceylon.

and silklike that it can be woven. Its chief use is as a tie material in nurseries and gardens.

Wickerwork

Hampers, baby carriages, chair seats, and even chairs and other light articles of furniture may be made from willows. Rattan and bamboo are also extensively used for these purposes.

Rattan is obtained from several species of climbing palms (*Calamus* sp.) found in the hot humid forests of the East Indies and other parts of tropical Asia. The stems of these plants are very long, strong, flexible, and uniform in size. They are used,

either entire or as splits, throughout Asia for baskets, furniture, canes, and a great variety of other purposes. A considerable quantity of rattan is exported to Europe and the United States.

Bamboos occur in most tropical countries, but they are especially common in the monsoon region of Eastern Asia. They are the largest of the grasses, with more or less woody stems which sometimes reach 1 ft. in diameter and 100 ft. or more in height (Fig. 21). The species are very numerous and belong to *Arundinaria, Bambusa, Dendrocalamus, Gigantochloa, Phyllostachys,* and other closely allied genera. The native uses of the bamboo are legion for all parts of the plant are of value. This is particularly true of the stems which are extensively used for all types of construction. Bamboo is shipped to other countries for use in the manufacture of furniture, fishing rods, implements of various kinds, and many other objects. Bamboo splits are utilized for baskets and brushes

FILLING FIBERS

A considerable number of plant fibers are used for stuffing pillows, cushions, mattresses, furniture, and similar articles. These filling fibers, as they are usually called, are also utilized in caulking the seams of vessels, in the manufacture of staff for building purposes, as stiffening for plaster, as packing for bulkheads and machine bearings, and for the protection of delicate objects during transportation. Surface fibers are commonly used for stuffing purposes, for their staples in general are too short to be spun readily and so are valueless for textile manufacturing. Bast fibers are too expensive, and hard fibers are likely to be too stiff and coarse. The silk cottons constitute the most important source of stuffing materials.

Kapok

Kapok is without question the outstanding silk cotton and the most valuable of all the stuffing materials. Its use is steadily increasing. Kapok is the floss produced on the seeds of the kapok tree (*Ceiba pentandra*). This species, originally confined to the American tropics, is now found in Asia and Africa as well. It is an irregular tree (Fig. 22) from 50 to 100 ft. in height, with a weird habit of growth. It grows very rapidly and begins to bear when only 15 ft. high. A mature tree produces about a

thousand pods and about 10 lb. of the cottony fibers. This floss (Fig. 23) is whitish, yellowish, or brownish in color. It is

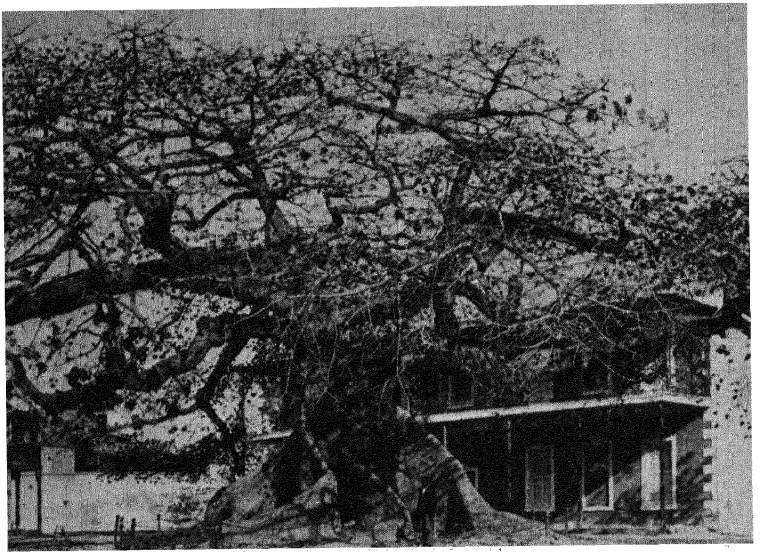


FIG. 22.—A kapok or silk cotton tree (*Ceiba pentandra*). Note the buttresses and the peculiar habit of growth.

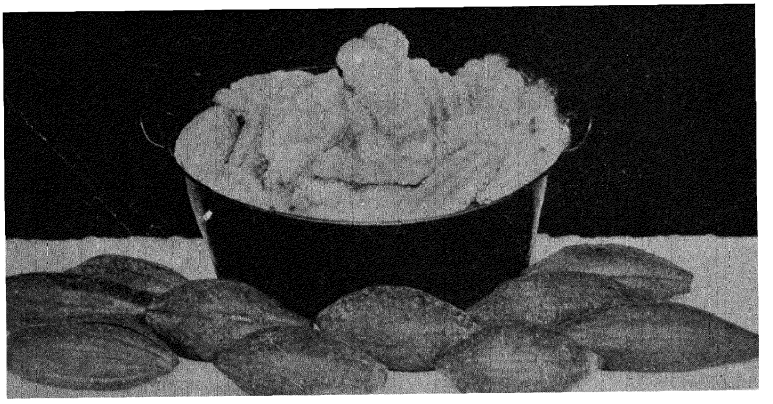


FIG. 23.—Kapok pods and a mass of the downy fibers produced on the seeds. This is the kapok of commerce, the most valuable of the stuffing materials.

very light, fluffy, and elastic, and so makes an ideal stuffing material for mattresses and pillows. The fibers have a very low

specific gravity and are impervious to water. For this reason kapok is valuable as a filling for life preservers, life cushions, and similar articles. The United States imports a large amount, chiefly from Java, the Philippine Islands, and Ceylon. Some of the supply comes from Mexico. Kapok seeds contain 23 per cent of a fatty oil which is extracted and used for soap and food purposes.

Other Filling Materials

The white silk cotton (*Cochlospermum Gossypium*) yields a kapoklike fiber of considerable importance. It is a handsome Indian tree, now widely cultivated in the tropics. This species is one of the sources of kadaya gum. The red silk cotton or simal (*Bombax Ceiba*), a very large and ornamental tree, supplies a reddish floss, which has been an important stuffing material in India for centuries.

The madar (*Calotropis gigantea*), a shrub that is found from India to the Moluccas, produces a silk cotton and also a bast fiber of some value. The closely related akund (*C procera*) yields a similar product. Although much inferior to kapok, these materials are frequently used in mixtures with kapok.

Several of the milkweeds, all of which have conspicuous silky hairs on the seeds, are used as a source of stuffing materials. Among them may be mentioned *Asclepias syriaca* of eastern North America and *A. curassavica* of tropical America. The latter species also yields a textile fiber.

Countless other plants and fibers are useful as filling materials. They include the straw of cereals and other grasses; corn husks; Spanish moss (*Tillandsia usneoides*), a conspicuous epiphyte of the southern states which makes an excellent substitute for horsehair; and *crin végétal*, the shredded and twisted fibers from the leaves of the dwarf fan palm (*Chamaerops humilis*) of Northern Africa and the Mediterranean region.

NATURAL FABRICS

Certain tree basts with tough interlacing fibers can be extracted from the bark in layers or sheets, which can then be pounded into rough substitutes for cloth.

Perhaps the best known of these bark cloths is **tapa cloth,** which constituted the chief clothing of the natives of Polynesia

and parts of Eastern Asia until half a century ago. This material is obtained from the bark of the paper mulberry (*Broussonetia papyrifera*). Strips of bark are peeled off the trunk, and the outer coating is scraped off with a shell. After they have been soaked in water and cleaned, these strips are placed on a log of hard wood and pounded with a mallet. The individual strips are united by overlapping the edges and beating them together. Depending on its thinness the finished product varies in appearance from a muslinlike material to a leathery one. Tapa cloth is often dyed.

Similar bark cloths have been manufactured from different sources by the native peoples of many other parts of the world. The South American Indians used the tauary (*Couratari Tauari*) and other species of the same genus. In Mozambique a wild fig (*Ficus utilis*) is used as the source of the native mutshu cloth. A common bark cloth of Ceylon and Malaya is obtained from the upas tree (*Antiaris toxicaria*), which is also the source of an important arrow poison.

The so-called **lace bark** is the product of *Lagetta lintearia*, a small Jamaican tree. The inner bark is removed in sheets and can be stretched into a lacelike material with pentagonal meshes. This is suitable for a number of textile and ornamental uses.

Cuba bast is obtained from *Hibiscus clatus*, a small bushy tree of the West Indies. The inner bark is removed in long ribbonlike strips, which are much used in millinery and for tying cigars.

A unique fiber is obtained from the **vegetable sponge** (*Luffa cylindrica*). This climbing cucumber of the tropics bears fruits that contain a lacy network of stiff curled fibers. This yellowish skeletal material is extracted by retting in water, and is much used in making hats and as a substitute for bath sponges. Japan exports large quantities of this material.

PAPER-MAKING FIBERS

An important use of fibers is in the manufacture of paper. This is a very old industry. The word "paper" comes from the Latin "papyrus," the name of a sedge, the pith of which was used for paper in Egypt as early as 2400 B.C. The Chinese, however, were the first people actually to make paper. The industry spread from China to India, Persia, and Arabia, and thence

through Spain to the European countries. The first paper mill in the United States was established near Philadelphia in 1690.

Raw Materials

Paper can be made from any natural fibrous material. The paper-making value of the various fibers depends on the amount, nature, softness, and pliability of the cellulose present in the cell walls. This cellulose may occur alone or in combination with



Fig. 24.—A pile of pulpwood in Somerset County, Maine. (*Photo by U.S. Forest Service.*)

lignin or pectin. The compounds of cellulose that occur in the artificial fibers, however, are not well suited for paper making. In the past a considerable number of raw materials have been prominent, and many others have been experimented with. At the present time, however, comparatively few are of commercial importance. Chief among these are wood fibers, cotton, and linen.

Wood Fibers

The use of wood as a raw material in the paper industry (Fig. 24) began in 1840 and dates commercially from 1854. Today wood has largely supplanted the other fibers and furnishes from

80 to 85 per cent of all the paper manufactured in the United States. The industry is still undergoing development in regard to the species utilized and the processes involved. Recent experiments with specially processed and purified wood pulp point to an even greater and more efficient utilization in the future.

Spruce is the most important source of wood pulp and furnishes about 30 per cent of the total supply. It is an ideal material for it has all the requirements of a good pulpwood. The fibers are long and strong with a maximum content of cellulose. The wood is almost free from resins, gums, and tannins; and it is light colored, sound, and usually free from defects. Red spruce (*Picea rubens*), white spruce (*P. glauca*), and Sitka spruce (*P. sitchensis*) are all used for pulp.

The second most important pulpwood at the present time is southern yellow pine (*Pinus palustris*). This species has had a remarkable rise in prominence in recent years and has outstripped the hemlock, which now occupies third place. The eastern hemlock (*Tsuga canadensis*) continues to be used, chiefly in the Lake States, while the western hemlock (*T. heterophylla*) is increasingly important on the Pacific coast. The aspens (*Populus grandidentata* and *P. tremuloides*) and the balsam fir (*Abies balsamea*) also furnish a considerable part of the supply.

Other less important species include jack pine (*Pinus Banksiana*), tamarack (*Larix laricina*), white fir (*Abies concolor*), and several hardwoods, among them the beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), and birch (*Betula lutea*). Sawmill waste is today an increasingly valuable source of wood pulp.

Cotton and Linen

Until the middle of the nineteenth century cotton and linen rags were the only source of paper, and they are still used for the finest grades. Cotton fibers have a high felting power and a high content of cellulose (91 per cent). Rags and raw cotton in the form of fuzz or linters are utilized. Flax fibers, which comprise linen, contain 82 per cent of pectocellulose and yield a paper of great strength, closeness of texture, and durability. Textile waste can also be used. In the preparation of rag pulp the material is sorted, cut into small pieces, and freed from dust. It is then boiled in caustic soda to remove the grease, dirt, and

dyes, and is washed until perfectly clean. The resulting pulp is ready for the actual operations involved in paper making.

Raw Materials of Minor Importance

Esparto.—The esparto grass (*Stipa tenacissima*) is an important raw material in Great Britain. The plant is a native of Northern Africa, where it flourishes in dry, sandy, and rocky coastal regions. The tufted wiry stems are plucked and pressed into bales for shipment. Esparto is converted into pulp by heating in a caustic-soda solution under pressure. Although the cellulose content is only 48 per cent, the fiber has great flexibility and felting power. It yields an opaque, soft, light paper of uniform grade. The finer printing papers in England are made from esparto, either alone or in mixture. Another grass, *Lygeum Spartum*, is sometimes used as a source of esparto.

Textile Fibers.—Many textile fibers in addition to cotton and flax have been used as sources of paper. The waste material of the jute and hemp industry, in the form of old ropes, sacking, sailcloth, and the like, was formerly used extensively for making strong and tough papers. Jute and jute butts were used chiefly for wrapping paper, envelopes, cable insulation, etc., while hemp, after bleaching, yielded ledger and bank-note paper. Manila hemp was an important source of envelopes and wrapping paper. Ramie, sisal, sunn hemp, New Zealand hemp, coir, and many other fibers have been utilized.

Paper Mulberry.—The soft, lustrous, and very strong bast fibers of this species, already discussed as the source of tapa cloth, have long been used in Japan for paper lanterns and umbrellas, as well as paper for writing purposes. The fiber is prepared by scraping, soaking, and beating, after which it is mixed with mucilage and spread on frames to dry. When treated with oil this paper becomes strong enough to serve as a substitute for cloth or leather.

Other Sources.—The raw materials mentioned above by no means exhaust the list of paper-making plants. The stems of wheat, rye, barley, rice, oats, and other grasses are used for low-grade paper, strawboard, cardboard, and pasteboard. The fibers from these plants have a low cellulose content, and are too short and small to have much tensile strength. They are consequently used in mixture with other fibers. In the United

States cornstalks, sugar-cane bagasse, and waste paper have been extensively developed as sources of paper. Even such unusual materials as banana fiber, tree bark, rushes, weeds, licorice, broomroot, tobacco and cotton stalks, beet-pulp waste, and peat have been experimented with.

Still other species are used in oriental countries. Bamboo fiber constitutes an important source of paper in India and China. The papyrus (*Cyperus Papyrus*), baobab (*Adansonia digitata*), and *Daphne cannabina* are much used in India and Africa. The so-called rice paper of China and Japan is made chiefly from *Tetrapanax papyriferum*, *Edgeworthia Gardneri*, or *Wickstroemia canescens*

The Manufacture of Wood Pulp

Wood pulp plays such an important part in the paper industry that it will be worth while to discuss briefly the methods by which it is manufactured. Either a mechanical process or one of three chemical processes is involved.

Mechanical Process

In this method the wood is barked, washed, and cut into small lengths. These bolts, as they are called, are forced against rapidly revolving stones or grinders, and the fibers are torn apart by abrasion. In the *cold method* a large amount of pure water is used to prevent heating, and a fine, even grade of fiber results. In the *hot method* very little water is used, and coarser, longer fibers are obtained. After grinding, the material is screened to remove any impurities and to grade it. It is then pressed between rollers to remove most of the water. Finally it is passed through a lapping machine which turns out flat layers of pulp. These can be made at once into paper, or they can be dried and shipped to consumers elsewhere.

In the mechanical process resins, lignin, and other undesirable materials are not removed. These substances resist bleaching agents and cause the paper to turn yellow. Furthermore the fibers produced do not felt readily. Mechanical pulp is poorest in grade, printing quality, strength, and durability. It is, however, the cheapest kind to manufacture. About 30 per cent of the pulpwood used is reduced by this method. Spruce is the

wood ordinarily used. About 85 per cent of the total consumption of this species is converted into mechanical pulp.

Chemical Processes

In these processes most of the foreign material is removed and almost pure cellulose is obtained. The wood is split and placed in a chopper, which produces coarse chips. These chips are screened to remove knots and large pieces, and are then subjected to one of three treatments.

In the **sulphite process** carefully selected chips are cooked with steam in a solution of acid calcium sulphite. This is prepared by burning sulphur to sulphur dioxide and passing this gas across broken limestone over which water is trickling. After digestion in the liquid the pulp is washed, screened, lapped, and dried. About 50 per cent of the pulpwood used is reduced by this method. Spruce furnishes two-thirds of the supply and hemlock and balsam fir the remainder.

The **soda process** lends itself to the reduction of hardwoods and pine. It is comparatively simple, involving the digestion of the wood under pressure in a solution of sodium hydroxide at a temperature of about 240°F., followed by washing, bleaching, and lapping. Aspen is the principal species used, although several other hardwoods and southern pine are utilized.

The **sulphate process** is the most recent method for the reduction of pulpwood, and offers promise of greater development in the future. It is adapted to coniferous woods with a high resin content. First used in 1883, it has always been prominent in Europe, and today it is of steadily increasing importance in the United States. In this country southern yellow pine and the waste from lumbering operations and sawmills supply much of the raw material. Hemlock, spruce, tamarack, jack pine, and balsam fir are also used. In this process the wood is digested in a solution of caustic soda, sulphide of soda, and a little sulphate of soda. After cooking in this mixture, the pulp is washed, screened, and pressed. The greater part of the sulphate pulp manufactured is used in making kraft paper, a strong brown wrapping paper. It may be bleached, however, and yields a white paper that is softer and more pliable than that made from sulphite pulp.

The Manufacture of Paper from Pulp

The actual process of paper making involves several steps, the first of which are concerned with the further treatment of the pulp. These include bleaching, washing, and the complete separation of the fibers. The latter operation is carried on in a machine known as a beater, or "Hollander." During this process sizing, usually rosin, is added to make the paper water- and ink-resistant. In some cases filling or loading materials are added which result in a more printable surface. Clay is commonly used for this purpose. If colored paper is required, the dye is added during the beating process. Mordants are usually necessary to fix the color, for cellulose is very inactive.

From the beater the pulp passes to the paper-making machine itself. This consists essentially of an endless wire screen revolving around a series of rollers. It is a modification of the original Fourdrinier machine, the first to make paper, which was invented at the beginning of the nineteenth century. The final stages of paper making are carried out in the presence of enormous quantities of water. They are mechanical and physical rather than chemical in nature. The pulp is poured on the screen and the water passes through, leaving a continuous sheet of interlacing fibers. This sheet is passed on to a felt and is carried to a series of heavy rollers where the water is squeezed out, and then through heated cylinders where the sheets are dried. Finally the paper is run through the calenders where a smooth finish is put on. The paper is then ready to be cut to any desired size.

Kinds of Paper

Different kinds of paper require different raw materials and modifications in the process of manufacturing. *Fine papers*, as they are called, include bond, ledger, book, writing, and similar papers. The best grades are made entirely from rags; medium grades are made from mixtures of rag and chemical pulp; the poorer grades contain only wood pulp. *Newspaper stock* is made chiefly from mechanical wood pulp. *Wrapping paper* comes from kraft pulp for the most part, although various textile fibers are still sometimes used as raw materials. *Blotting paper* is composed of short fibers loosely interwoven and free from loading or sizing. Formerly it was prepared entirely from rags,

but today soda pulp is being used more and more. *Cardboard* and *pasteboard* are made from straw, or any other low-grade material, including a large amount of old newspapers, boxes, and other waste paper. It is sometimes made by sticking layers of paper together in a special machine. *Papier mâché* consists of old paper stock boiled to a pulp, mixed with glue and starch paste, and pressed into molds. *Vegetable parchment* is prepared by dipping finished sheets of paper in sulphuric acid and then washing with water and ammonia *Roofing* and *building papers* and many other special types are manufactured by treating paper with wax, tar, asphalt, oils, resins, or other substances

1935 IMPORTS OF IMPORTANT RAW FIBERS

Abacá	43,687 tons	Istle	8,747 tons
Broomcorn	2,646 short tons	Jute	51 774 tons
Broomroot	28,512 lb	Jute butts	10,763 tons
Coir	848 tons	Kapok	12,385 tons
Cotton	14,797 tons	Maguey	1,611 tons
Crin végétal	5,495 tons	Palm leaves	23,367 tons
Flax	3,367 tons	Raffia	158 tons
Hemp	764 tons	Ramie	2 tons
Henequen and sisal	125,931 tons	Sunn hemp	561 tons

CHAPTER III

FOREST PRODUCTS: WOOD AND CORK

FOREST PRODUCTS

The products of the forest have been of service to mankind from the very beginnings of his history. The most familiar, and the most important, of these products is wood, the manifold uses of which in all types of construction, as a fuel, and as a raw material of the paper and rayon industries are well-known to everyone. Wood, however, is by no means the only useful material obtained from trees. Other products include cork, rubber, many of our tanning materials and dyestuffs, resins, gums, oils, drugs, and even sugar, starch, and various chemicals. Moreover the seeds and fruits of many trees often serve as food for man or beast.

Not only are these forest products of value to man, but the forests themselves have many utilitarian features. They help to regulate climate and temperature. They aid in the conservation of the water supply and in flood control by preventing the runoff of water. Their deep roots hold the soil firmly in place and so check erosion. Again they may act as shelter belts against drying winds. In addition forests afford a shelter for wild life, and offer many recreational aspects for man, the importance of which is just beginning to be recognized.

Our discussion of forest products, as such, will be limited to wood and cork, which will be treated in the present chapter. The other useful materials obtained from trees will be considered in later chapters together with similar economic products from other sources.

THE IMPORTANCE OF WOOD

From the earliest time clothing, shelter, and food have been the three great necessities of mankind. We have already discussed in Chap. II the importance of fiber plants as a source of shelter and of clothing. Wood has been fully as important, and

has contributed its share to the advancement of civilization Primitive man not only used wood in the construction of his rude shelters, but was able, even with the crude stone implements at his disposal, to fashion dugout canoes, implements, and utensils of various kinds. At a later period when metal tools became available the uses of wood increased greatly When we stop to consider that from the dawn of history to the middle of the last century all ships were made of wood, the influence that this material had on the course of history is obvious If no wood suitable for seagoing vessels had existed, the great voyages of exploration, the colonization of the newly discovered lands, and many other events that have led to the development of the world as we know it today would have been impossible.

Today wood is the most widely used commodity outside of food and clothing, and for many purposes it has no satisfactory substitute. It will probably continue to be indispensable in spite of the competition of the various metals, for it is the only raw material in its field that can be renewed. Wood has many other advantages over the metals. It is the most readily available of all raw materials, and with proper care the supply should be inexhaustible. It is cheaper, lighter, more easily worked with tools, and more easily fastened together; wooden structures can be readily altered, moved, or rebuilt. Wood is very strong for its weight, and in its combination of strength, elasticity, and toughness it has no rival. It is a poor conductor of heat, electricity, and moisture and does not rust or crystallize. Its beautiful figure makes it preeminent as a material for fine construction. It is also possible to use wood in the form of thin sheets or veneers. It must not be assumed from the above statements that wood is superior to metals in every respect, for it does have certain very definite disadvantages.

THE STRUCTURE OF WOOD

Wood is a secondary tissue produced chiefly in the stems of gymnosperms and dicotyledons as the result of the activity of a growing layer, the *cambium*. This tissue is responsible for the growth of stems in thickness through the formation each year of new layers of both wood and bark. The nature of this process and the details of wood anatomy are too familiar to students of botany to need much amplification here.

Nature of the Wood Elements.—Wood is a heterogeneous tissue composed of several different types of cells, some of which have the function of mechanical support and others that of conduction. In the softwoods, as the woods of gymnosperm origin are commonly called, both these functions are normally carried on in cells known as *tracheids*. In the hardwoods, which comprise woods of angiosperm origin, on the other hand, a division of labor usually occurs. Mechanical support is furnished by the several types of *wood fibers*, which make up a large part of the woody tissue, while conduction of water is carried on in tubular cell fusions known as *vessels*. Tracheids also may occasionally be present. A third function of the wood elements, the distribution and storage of carbohydrate food, is carried on in the thin-walled *parenchyma cells*. These are the only components of wood which can be said to be alive and which contain protoplasm. They may be wood parenchyma cells, which have a vertical arrangement in the stem, or ray parenchyma cells, which are horizontally arranged.

Diagnostic Features of Woods.—The arrangement of the various types of cells in different species affords valuable diagnostic characteristics for the identification of woods, besides making possible the distinctive features that are of commercial importance. Among the gross morphological characteristics that are of value in distinguishing between woods may be mentioned pores, early wood and late wood, growth rings, rays, sapwood and heartwood, and grain and figure.

Porous and Nonporous Woods.—The presence or absence, and the nature and arrangement (as seen in cross section) of *pores*, which are cross sections of vessels, serve as a ready means of classifying woods (Fig. 25). Coniferous woods, in which vessels and consequently pores are typically absent, are classed as *nonporous* woods. The porous woods comprise the hardwoods, and two distinct types are recognizable. In some woods, like ash, elm, hickory, and oak, the pores seem to be arranged in concentric circles, the outer and inner portions of which differ with regard to the number and size of the pores. This condition is due to the fact that large vessels are formed at the beginning of each season and smaller ones later on. Such woods are termed *ring-porous*. In other woods, like beech, birch, maple, and walnut, the pores are all small and approximately of the same

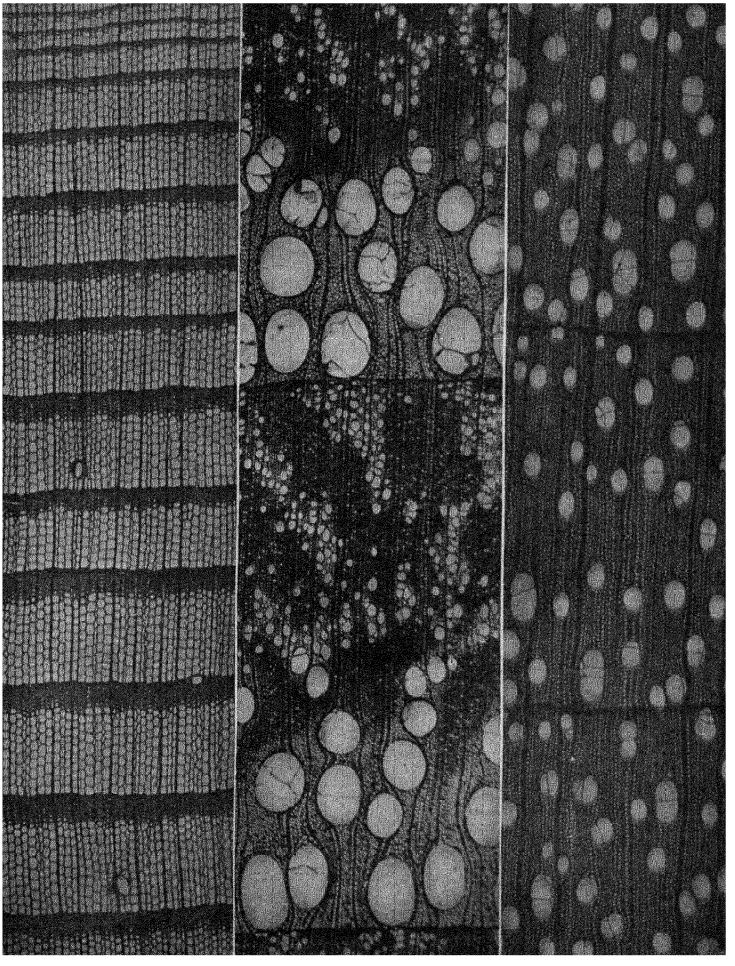


FIG. 25.—*Left*, a nonporous wood, western larch (*Larix occidentalis*); *center*, a ring-porous wood, chestnut (*Castanea dentata*); *right*, a diffuse-porous wood, yellow birch (*Betula lutea*). (*Reproduced from Holtman, Wood Construction, McGraw-Hill Book Company, Inc.*)

size and they are scattered uniformly through the wood. These are the *diffuse-porous* woods.

Early Wood and Late Wood.—In temperate regions new wood is formed each year during a limited growing season and definite growth layers result, which usually show two distinct areas within each layer. In the spring when growth is resumed, the first wood to be formed contains many large and relatively thin-walled cells, in response to the greater need for conducting elements. This is the early wood, or spring wood, as it has been called. As the season progresses a denser type of wood is laid down with smaller, thicker walled cells, the so-called late wood, or summer wood. As a result of this there is a sharp transition between the cells produced at the end of any one growing season and those formed at the beginning of the succeeding one. This gives rise to what appear in cross section as concentric rings, known as growth rings. The growth ring of a single year is called an annual ring, and the number of these annual rings gives an indication of the age of the tree. In the tropics where growth may be continuous throughout the year, growth zones may occur, but they are due to changes in climate or other causes rather than to definite growth periods as is the case in temperate woods

Rays.—The rays are thin sheets or ribbons consisting chiefly of parenchyma cells that are oriented at right angles to the main axis of the stem. They vary greatly in width, height, and arrangement. Although visible in a cross section as lines radiating from the center of the stem, rays are most conspicuous in radial sections, where they frequently contribute valuable diagnostic features in the variety of their form and arrangement.

Sapwood and Heartwood.—Although at first all the cells in wood are physiologically active, sooner or later many of them lose this property and become mere skeletons, serving only to give strength to the tree. Eventually two distinct areas develop—a light-colored outer region of varying width, the sapwood; and a darker inner region, the heartwood. Only the cells in the sapwood are physiologically active, and even in this region only the parenchyma cells can be said to be alive. The older, dead cells of the heartwood often become highly colored and very resistant to decay, owing to the deposition in them of various gums, resins, or other waste materials. Such heartwood is usually capable of

a high polish, and is in great demand in the cabinetmaking, furniture, and other high-grade woodworking industries. Although heartwood is usually quite distinct from sapwood in appearance, durability, and other properties, it may not always be so clearly differentiated.

Grain and Figure.—Grain, figure, and also texture are terms that are likely to be used in a more or less confusing manner. Strictly speaking, *texture* refers to the relative size and quality of the various wood elements, while *grain* refers to their structural

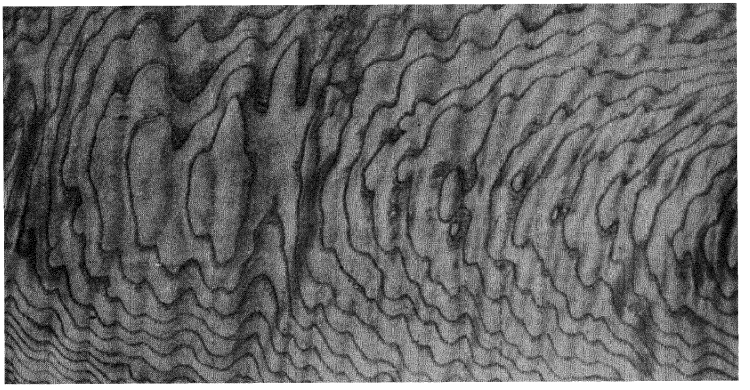


FIG. 26.—Wavy grain in white ash (*Fraxinus americana*). The light areas are late wood, the wavy dark lines early wood. (*Courtesy of S. J. Record.*)

arrangement. *Figure,* on the other hand, applies to the design or pattern that appears on the surface of lumber, and may be due to the kind of grain, the presence of coloring matters that have penetrated the tissues, or both.

Only a few of the many kinds of grain can be mentioned here. In straight-grained wood the various elements occur parallel to the main axis of the stem. Where they are spirally twisted about the axis they constitute spiral-grained wood; and when the longitudinal course of the elements is slightly undulating, wavy grain (Fig. 26) results. Curly grain is due to various irregularities of growth and a diversity of causes.

The attractive and distinctive figures which wood often shows and which make it so valuable for decorative purposes are due chiefly to the different types of grain in combination with the rays, rings, sapwood, heartwood, and the many other cell arrange-

ments. It is possible to accentuate one or another of these variations by using different methods of cutting the wood. In quartersawing, for example, wood is cut parallel to the rays and across the rings, while in plain sawing the wood is cut at right angles to the rays and tangent to the rings. Both quartersawed and plain-sawed wood have their own desirable qualities. Occasionally figures in wood are produced by masses of coloring matter which has penetrated the tissues and which may occur in zones or streaks. In the case of snakewood (Fig. 27) streaks

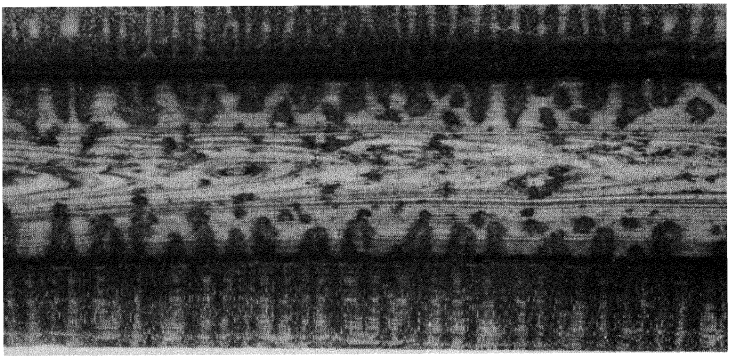


FIG. 27.—Figure in snakewood (*Piratinera guianensis*). The streaks of coloring matter that have penetrated the tissues suggest the markings on a snake skin. (*Courtesy of S. J. Record.*)

on the tangential surface suggest the markings on the skin of a snake.

THE MECHANICAL PROPERTIES OF WOOD

Wood possesses certain mechanical properties which, either alone or in combination, determine its usefulness and suitability for various purposes. These characteristics differ in different species and even in individual trees. Many tests have been devised to determine the exact nature of the properties that any specific wood may possess, for this information is essential for the consumer.

The mechanical properties of wood are those properties which enable it to resist various external forces that tend to change its shape and size and produce deformations. These external forces induce internal resisting forces, known as stresses, in the wood.

When the latter exceed the force of cohesion among the wood elements, some sort of failure occurs. Among the more important mechanical properties may be mentioned strength, stiffness, toughness, hardness, and cleavability.

Strength.—Although strength is sometimes used to mean all the mechanical properties of wood, it should more properly be restricted to the ability to resist certain definite forces, such as crushing, pulling, and shearing. Moreover the word should always be modified to indicate the specific type of resistance involved.

Crushing Strength.—Crushing or compression strength is the resistance offered to forces that tend to crush wood. These forces may be applied endwise, and so parallel to the grain, as in a column; or sidewise, where they are at right angles to the grain, as in the case of railroad ties. The maximum crushing strength is endwise.

Tensile Strength.—Tensile strength is the resistance to forces that tend to pull wood apart, and these also may be applied either parallel to or at right angles to the grain. The maximum tensile strength occurs when the force is parallel to the grain, and it is two to four times greater than the crushing strength.

Shearing Strength.—Shearing strength is resistance to those forces which tend to make the fibers slide past one another. These forces may be applied parallel to the grain, at right angles to it, or obliquely. Wood is more resistant to a perpendicular shear.

Cross-breaking Strength.—The cross-breaking, or bending, strength of wood is usually applied to beams or other pieces of timber that are supported at both ends and loaded between these points. The strength involved is the resistance to forces that cause the beam to break, and all the above-mentioned forces are involved. The upper part of the beam is under compression, the lower under tension, and shearing also plays a part. Because of its greater tensile strength, a beam fails first by compression, or buckling, on the upper side; then, as the load increases, the tensile strength gradually fails until the beam snaps across on the underside.

The strength of wood is the most important factor in determining the value of any species for structural purposes. It is a very variable property, however, and is influenced by the density of

the wood, the moisture content, the presence of defects, and many other factors. The relationship between density and strength is particularly close, so much so that density is considered to be the most satisfactory criterion of strength. Longleaf pine, larch, hickory, sugar maple, and white oak are among the strongest native woods.

Stiffness.—Stiffness is the measure of the ability of wood to resist forces that tend to change its shape—in other words, its capacity to withstand deformation under a bending strain. This is often contrasted with flexibility, which is the ability to bend without breaking and which involves toughness and pliability.

Toughness.—Toughness is used in several senses, but it is usually considered to mean the ability of wood to absorb a large amount of energy, and so resist repeated, sudden, sharp blows or shocks. It is really a combination of other properties. A tough wood is hard to split, and, although it may rupture, it does not break readily.

Hardness.—Hardness is the measure of the power of wood to resist indentations, and also abrasion and wear. It varies with the density and determines the ease with which wood can be sawed or cut.

Cleavability.—Cleavability is an expression of the ease with which wood can be split. It is a particularly desirable quality in the case of firewood, and equally undesirable when wood must be able to hold nails or screws. Wood tends to split more easily along the rays and when it is straight grained.

FACTORS THAT INFLUENCE THE MECHANICAL PROPERTIES OF WOOD

Although there are many factors that influence the strength, hardness, and other properties of wood to a greater or less extent, space will permit the mention of only a few of the more important ones, such as density, moisture, and a few of the defects.

Density.—Differences in density—the ratio of the mass of wood substance to its bulk—are among the chief causes of variations in the mechanical properties of wood. It has already been pointed out that, because of the close relationship between the two properties, the density of any wood may be considered the best indication of its strength. Density is usually expressed in

terms of *specific gravity*, which is relative density. Whereas density is merely the weight of a unit volume of any substance, and is expressed as weight per cubic foot, specific gravity is the ratio between the weight of the substance concerned and that of an equal amount of pure water.

The density of wood substance is practically the same in all species, and its specific gravity has been estimated as about 1.55. This means that wood is 1.55 times heavier than water, which explains the fact that a piece of wood sinks as soon as the air in the cavities has been replaced by water. The variations in density, however, which are to be noted in different species, individuals, and even parts of the same individual, are due to differences in the actual amount of wood substance present in other words, to the amount of cell-wall material as compared with cell cavities. Woods with thicker walls and smaller cavities are denser and heavier, while the more porous woods with larger cavities and thinner walls are lighter and less dense.

The specific gravity of wood may be determined in several ways, but usually the weight is calculated from oven-dry material, and the volume is measured with the wood in any desired condition. However, since the moisture content of green, partly seasoned, and seasoned wood is quite different, and since this difference materially affects the specific gravity, it is obvious that figures for specific gravity mean little unless the condition of the wood under which the calculations were made is stated.

Since the amount of actual wood substance has such an important bearing on the density of a piece of wood, it might be assumed that heavier woods are necessarily stronger. This is not always the case for the presence of gums, resins, or other infiltrated substances and also the amount of water may affect the weight without altering the strength.

Oak, hickory, persimmon, and osage orange are among the heaviest native woods. It is often stated that tropical woods are heavier than temperate woods. That this is not the case is evidenced by the fact that both lignum vitae, the heaviest commercial wood, and balsa, the lightest, are products of the tropics.

Moisture.—Wood always contains more or less water, the amount in green wood varying in different species and under different conditions from as low as 40 per cent to as high as

100 per cent or more of the dry weight. The water in wood occurs in the cell cavities or in the cell walls, in which case it is known as *hygroscopic water*. The amount of hygroscopic water necessary to saturate the walls is called the *fiber-saturation point*, and constitutes from 20 to 35 per cent of the dry weight. The variation in the amount of water that may be present in wood is due to a number of causes, and is made possible by a characteristic property inherent in the wood. This property, which is known as *hygroscopicity*, is the ability to absorb or give off water under different conditions, with an accompanying swelling or shrinking as the case may be.

As already stated, the moisture content of wood has an important bearing on its weight, density, and often on its strength. If the amount of water present is above the fiber-saturation point, the weight is increased, but the strength is not altered. If, however, the amount of water is brought below the fiber-saturation point through evaporation, then the strength and other mechanical properties as well are changed. This means that it is only the loss of hygroscopic water which is responsible for the increase in strength that accompanies seasoning, as the drying out of wood is called. This loss of hygroscopic water causes the wood to shrink, owing to changes that take place in the cells. As the water passes off, the walls contract, the cells become more closely compacted, and the fibers become stronger and stiffer. This tendency of wood to shrink as it dries is one of the great drawbacks to its use. The amount of shrinkage varies greatly under different conditions, and it is likely to occur unequally and unevenly. Wood, for example, shrinks very little lengthwise, and only about half as much radially as tangentially. As the result of uneven shrinkage, warping, checks, shakes, and other defects may develop, which tend to counteract any increase in strength. In spite of these shortcomings, however, dried or seasoned wood is for the most part stronger, harder, stiffer, and more durable than unseasoned wood. Its desirability is great enough so that artificial methods of seasoning are utilized in an attempt to control the process as far as possible.

Artificial Seasoning.—The two chief types of artificial seasoning are air seasoning and kiln drying. In *air seasoning*, the moisture is removed by exposure to air without resorting to artificial heat. It is carried out in the open until the wood

ceases to lose weight. The final moisture content varies from 12 to 30 per cent, depending on the species, the duration of the process, and the weather conditions. The principal objects of air seasoning are to reduce the weight, the amount of shrinkage, and possible defects; to render the wood less subject to decay; to increase its strength and combustibility; and to prepare it for painting, preservative treatment, and kiln drying.

In *kiln drying*, heat is applied to wood in an enclosed space. Either unseasoned or seasoned wood can be utilized. The moisture is removed more rapidly and more completely, the moisture content of the finished product varying from 4 to 12 per cent. If green lumber is kiln dried, checks, warping, and defects due to fungi or insects may often be prevented.

Defects.—The mechanical properties of wood are frequently affected by the presence of various types of defects, which may be of major or minor importance. These defects are due to a considerable diversity of causes. As noted above, certain defects may develop during the seasoning of wood; others, such as knots and cross grain, may be inherent in the wood structure; still others may be due to external agencies. Among the latter may be mentioned insects, fungi, marine borers, birds, parasitic seed plants, frost, lightning, and fire. Defects due to insects and fungi are the most important.

Insect Damage.—The damage to wood resulting from insect injuries is far greater than is usually realized, amounting to about $9,000,000,000 annually. All sorts of wood from standing timber to lumber and wood products may be attacked. Holes produced by wood-boring insects constitute the chief type of injury. Insects are most destructive when in the larval stage. In recent years the ravages of termites, or "white ants," have been increasingly serious.

Decay.—Decay in wood is caused by fungi. Four conditions are essential for the development of these lower plants. Unless a favorable temperature, sufficient moisture, at least a small amount of oxygen, and an adequate food supply are available, fungous decay does not occur. The food supply is furnished by the cellulose and lignin in the cell walls, and is made available by enzymes, which are secreted by the fungi. The so-called brown rots remove the cellulose, leaving behind a brittle brown mass of lignin compounds; the white rots utilize the lignin and

leave the white cellulose behind. Still other fungi are able to utilize both cellulose and lignin.)

(Woods vary greatly in their natural resistance to decay. This property is known as *durability*, and is so important that it alone may determine the ultimate use of wood, especially in the case of posts, poles, mine timbers, etc., which are exposed to moisture. (Sapwood decays more readily than heartwood, for the latter often contains resins, gums, tannins, and other substances that resist fungous activity.) Seasoned wood is also less

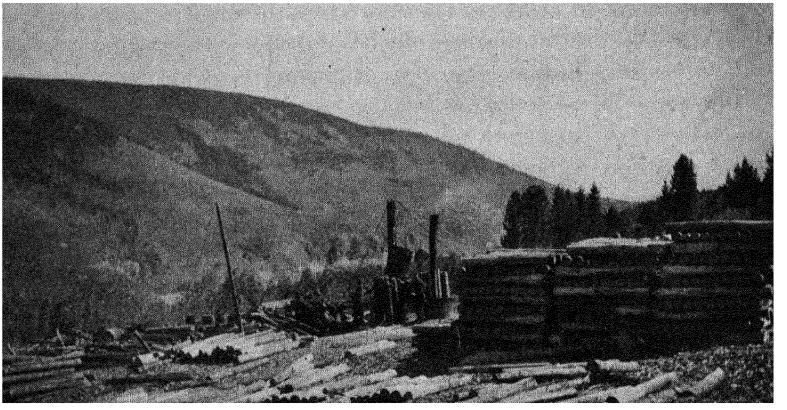


FIG. 28.—A creosoting plant in the Holy Cross National Forest, Colorado. (*Photo by U.S. Forest Service.*)

apt to decay because of the lower moisture content.) Among native woods that are naturally very durable may be mentioned the (cedars, redwood, cypress, osage orange, and locust;) the least durable woods include basswood and balsam fir.

Since the greatest possible durability of wood and wood products is highly desirable, it is frequently the practice to render the wood more immune to decay by treating it with preservatives that are poisonous to fungi. This process of *wood preservation* has developed into a considerable industry in recent years (Fig. 28). Various chemicals are used as preservative agents, chiefly creosote, a coal-tar product; and zinc chloride. The methods used are brushing or spraying the surface, dipping in open tanks, and various pressure processes that make possible a deeper penetration of the liquids.

THE USES OF WOOD

The uses of wood are so many and so varied that it will be impossible to discuss them at length within the limits of the present volume. It will also be impracticable to cite definite figures regarding the amount of wood and wood products utilized, since conditions vary so much from year to year. Anyone desirous of obtaining such figures may do so from government reports and other sources. For purposes of comparison, however, some such data are desirable, and consequently reference will be made to a few of the figures published in Zon and Sparhawk's "Forest Resources of the World." According to these authors the total annual consumption of wood in the world amounts to 56,000,000,000 cu. ft. Of this amount 28,000,000,000 cu. ft. (50 per cent) is used in North America, 17,000,000,000 cu ft. in Europe, 8,000,000,000 cu. ft. in Asia, 2,500,000,000 cu. ft. in South America, and the remainder in Africa, Australia, and Oceania. The United States uses about 24,000,000,000 cu. ft. The per capita consumption in North America is 188 cu. ft., a figure five times greater than that for any other continent. For the United States it is 228 cu. ft. This is significant when compared with Great Britain's 15 cu. ft , France's 26 cu. ft., and Germany's 27 cu. ft. It must be stated, however, that in other countries where the forests are still abundant the per capita consumption is even greater than in the United States.

In view of the fact that six times as much wood is cut in the United States each year as is replaced by normal growth, it is obvious that the present rate of consumption cannot continue indefinitely. This does not mean necessarily that all the forests are doomed to extinction. There is every reason to believe that under proper management and with adequate methods of conservation in the future there is sufficient potential forest area in the United States to supply our needs, particularly since our requirements are diminishing.

Of the 24,000,000,000 cu. ft. of wood cut in the United States annually about 43 per cent is used for fuel; 38 per cent for lumber; 9 per cent for fence posts, mine timbers, poles, and piling; 2 per cent for pulpwood; 1 per cent for cooperage; and the remainder for cross ties, shingles, laths, veneers and plywood, excelsior, distillation, and as a source of tanning materials.

Fuel

Fuel is one of the great necessities of modern life and it is indispensable, both in the home and in industry, as a source of heat and power. Any material that burns readily in air can be utilized, and a great variety of plant products are so used. The most important of these are wood, peat, and coal, which represent different stages in the carbonization of the original plant tissue.

Wood.—Even though much less wood is used for fuel at the present time than formerly, the total consumption is greater than for any other purpose. It is difficult to obtain reliable figures regarding the amount used, for much of the supply is obtained from small wood lots and other local sources. It must amount to over 100,000,000 cords, an equivalent of over 50,000,000 board feet. Farms and rural communities account for 90 per cent of the total, with the Southern and Western states using more than the rest of the country. The extensive use of wood for fuel does not represent a proportional drain on the forest resources, for much waste material is used, as well as wood unfit for other purposes.

Wood makes an excellent fuel since it is 99 per cent combustible when perfectly dry, and so leaves only a small amount of ash. It is also a flaming fuel and well adapted for heating large surfaces. The value of any particular wood for heating purposes depends on the amount of moisture present; thus seasoned wood is obviously better than green wood. Hardwoods have the greatest fuel value, especially such woods as hickory, oak, beech, birch, maple, and ash. In the South longleaf pine is used, while in the West favorite species include Douglas fir, western yellow pine, western hemlock, and western larch.

Peat.—Peat consists of deposits of vegetable matter which have accumulated in bogs and swamps and slowly decomposed, becoming somewhat carbonized and compacted (Fig. 29). The various plant tissues can still be made out. The process of peat formation is constantly going on. Peat is a valuable fuel in countries where wood is scarce. It is more bulky to handle, and leaves from five to fifteen times as much ash.

At the lowest depths of some peat bogs a soft brown coal, known as **lignite,** may be found. This also has the original plant structure still visible.

Coal.—Coal comprises the fossilized remains of plants that lived in former geological periods. The original plant tissue has been more fully decomposed and converted into carbon. Coal is much harder and more compact than peat or lignite, and has a greater heating power. It also yields a larger amount of smoke and ash. Anthracite or hard coals are the oldest and contain about 95 per cent carbon. Bituminous or soft coals are of more recent origin and consequently are less completely carbonized;

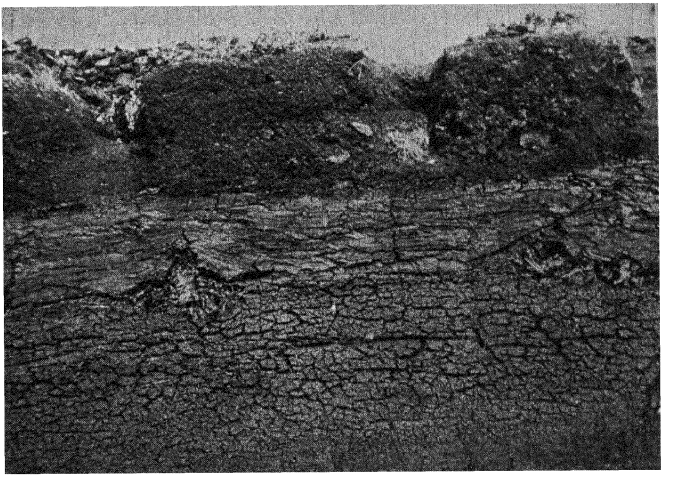


FIG. 29.—Section of a peat deposit several feet in depth. (*Reproduced from Weaver and Clements, Plant Ecology, McGraw-Hill Book Company, Inc.*)

they tend to soften and fuse at temperatures below the combustion point. Cannel coal consists of fossilized spores. It is very compact and oily and burns with a candlelike flame. Unlike other coals it does not soil the hands.

Coal is a cheap source of power and heat, and also of many valuable chemical products. Among the latter, which are obtained by destructive distillation, may be mentioned oils, such as benzol and naphtha; coal gas, which is used for fuel and illuminating purposes; ammonia; coal tar, the source of dyes, antiseptics, and countless other materials; and coke.

Coke bears the same relationship to coal that charcoal does to wood. It is obtained by the smothered combustion of coal in piles or special ovens, usually as a by-product of the illuminating-

gas industry. It is nearly pure carbon and burns without smoke or flame. Coke is an excellent fuel, and is also used in metallurgy.

Petroleum.—Although no trace of the original structure remains, it is generally supposed that petroleum had an organic origin and was formed under pressure from the minute floating plant and animal life of former shallow seas. Crude petroleum has many uses, but the substances derived from it by fractional distillation are even more important. Among these products may be mentioned gasoline, kerosene, vaseline, and paraffin.

LUMBER

Wood, in the form of lumber, has been used for building purposes and other types of construction from the earliest days in the history of the United States. This demand for lumber led to the establishment of a lumber industry at an early date. The first sawmill was started in Maine in 1631. From this beginning there has gradually developed a huge industry, which today ranks third in importance. The total output is around 40,000,000,000 board feet annually, a figure larger than that of any other nation.

The term "lumber," as generally used, means wood that has been prepared to some extent for future use. The larger sizes of lumber, intended for heavy construction, are often referred to as "timber." This term, however, is also frequently used for the forest trees themselves. The standard unit of measuring lumber is the board foot, which is the equivalent of a piece of wood 1 in. thick, 12 in. wide, and 1 ft. long.

The Lumber Industry

During the long history of the lumber industry in the United States there have been many changes in the location of this industry, in the species utilized, and in the actual woods operations.

The center of the industry has always been in a region where large stands of virgin timber were available. Until 1830 Maine was the principal lumber-producing state, and for the next 40 years New York and Pennsylvania led. By 1870 the center had shifted to the Lake States, with first Michigan and later Wisconsin assuming the lead. From 1910 on, the Southern states became the leaders, with southern pine replacing the northern hardwoods

and white pine. More recently the center has moved to the Pacific Northwest and is utilizing the immense stands of Douglas fir and other softwoods. At the present time the Southern states as a group still produce the most lumber, although Washington and Oregon are the leading individual states The Northwestern states must eventually assume the leadership, for over half the remaining timber supply is located in this region.

Since the beginning of the lumber industry some 150 native species have been utilized. The softwoods, however, have furnished about 78 per cent of all the lumber cut For many years the eastern white pine was the outstanding timber tree, and indeed was one of the most valuable trees in the whole world The demand for it was so great that the supply soon became greatly diminished and it was replaced in importance by other species. Oak and hemlock have also had their heyday At the present time the most important trees are southern yellow pine, Douglas fir, western yellow pine, oak, hemlock, white pine, and red gum, each of which yields more than 1,000,000,000 board feet of lumber. The first two of these, however, produce twice as much as all the others together Many woods that at one time were considered worthless are of commercial importance today. Examples include red gum, sycamore, beech, and tupelo.

In the early days the original forests were so abundant that the timber supply was thought to be inexhaustible. As a result the lumbering operations were usually very wasteful. At times every bit of wood would be stripped from an area, leaving only great quantities of slash as an ever-present fire hazard and in other ways rendering the region unfit for future forests. Or all the finest specimens would be cut, leaving only inferior trees, so that little or no reproduction was possible. The inferior quality and quantity of our eastern forests bear witness to these wasteful methods. In recent years, however, there have been many improvements in lumbering operations looking toward an elimination of waste and more complete and efficient utilization of the present supply, together with conservation and maintenance of a supply for the future.

The Utilization of Lumber

About 8 per cent of the lumber cut each year is exported; 32 per cent is used for structural timbers and rough lumber for con-

struction; 33 per cent goes to the planing mills; and 27 per cent is used in other woodworking industries.

Export Lumber.—The exporting of lumber has been an important item in American foreign trade since the early days of New England, and it increased in amount until the World War. Great Britain and the West Indies have been good customers, and in recent years there has been a considerable export business with Mexico, several of the South American countries, Australia, New Zealand, Germany, Italy, China, and France.

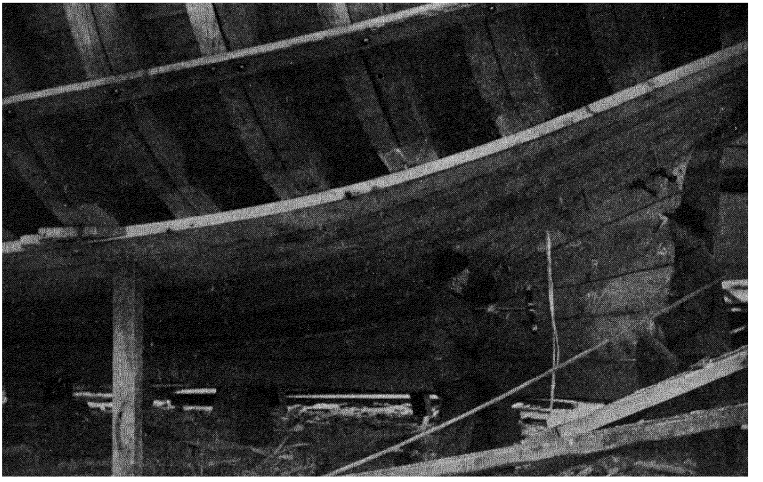


FIG. 30.—Structural timbers used in shipbuilding. (*Courtesy of S. J. Record.*)

Structural Timbers.—Structural timbers are the large sizes of lumber that come from the sawmills, and are used for bridges, buildings, and other types of heavy construction. They include beams, girders, stringers, posts, joists, rafters, planks, caps, sills, and boards for sheathing, roofing, and flooring, Before wooden vessels were replaced to such an extent by steel vessels, immense quantities of heavy timbers were used in shipbuilding (Fig. 30). Structural timbers are obtained chiefly from the softwoods because large sizes are more readily available. The timbers are usually sawed from the heart of the tree, and, even though defects may be present, the bulk is so great that the strength is not impaired. Strength is the chief requirement of a good structural timber, particularly the resistance to stresses that can be esti-

mated. Numerous timber-testing experiments have made possible the estimation of the working stresses with remarkable accuracy. Soundness, durability, and ease of working are other desirable characteristics. The principal species used in the United States for structural timbers are southern yellow pine, Douglas fir, hemlock, eastern white pine, western yellow pine, spruce, larch, and redwood.

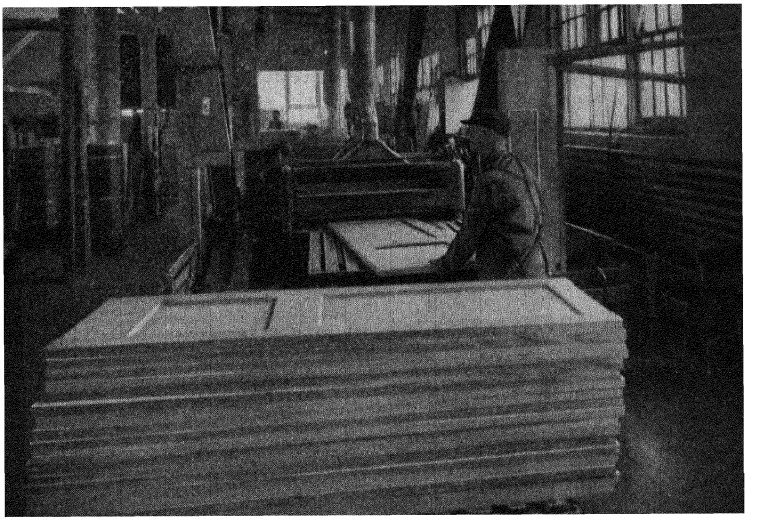


FIG. 31.—Sanding, the last process in the manufacture of doors, an important product of planing mills. *(Reproduced by permission from Atwood, United States among the Nations, Ginn and Company.)*

Planing-mill Products.—Planing mills, which are often associated with sawmills, use a large amount of lumber representing some 60 different species. Their products are sometimes classified as "factory lumber," which is lumber that has been recut to smaller dimensions and reworked. The chief products of the planing mills are sashes, doors, (Fig. 31), blinds, window frames, and interior finish. The best wood for millwork has a straight grain and soft uniform texture. It must not shrink or swell, and it should be easy to work and capable of taking paints and varnish. The cheaper products are made from white pine, yellow pine, Douglas fir, and other softwoods. For the more expensive products, oak, birch, red gum, walnut, maple, mahog-

any, and other hardwoods with a fine figure are utilized. Veneers are now being used extensively for door panels.

Interior finish includes baseboards, cornices, columns, grills, mantels, balusters, stairwork, posts, scrollwork, porch work, and trimming. Almost all the native and imported woods that are decorative and have good wearing qualities are used for these purposes.

Hardwood flooring has been a comparatively recent development of the planing mills, and is widely used. Only the most durable woods, which also have attractive figures, are used. These are kiln dried and thoroughly seasoned. The woods chiefly utilized are maple, beech, birch, oak, tupelo, and yellow pine.

Other Woodworking Industries.—Woodworking industries other than planing mills use about 27 per cent of the lumber cut. These industries are so numerous and their requirements and products so varied that it will not be possible to discuss them. The majority use a relatively small amount of wood, less than 1 per cent. A few, however, are more important. These include the box and crate, railroad car, furniture, vehicle, agricultural implement, and woodenware industries.

Boxes and Crates.—The manufacture of boxes, crates, baskets, and other containers for the transportation of canned goods, farm products, and a host of other articles is steadily increasing. The industry uses about 4,500,000,000 board feet, or 11 per cent of the lumber cut, as well as a large amount of veneers and timber in bolt form For box-making purposes wood should be light, strong, and easy to work, with good nail-holding power and a surface that can be printed upon. Lower grades of softwood lumber and the softer hardwoods are used. The chief species utilized are southern pine, western yellow pine, white pine, red gum, hemlock, and spruce

Furniture and Fixtures.—The manufacture of furniture requires wood of special strength, hardness, and durability. It must not shrink or warp, and should be ornamental and capable of a high polish. Oak, maple, birch, walnut, and red gum are the most important native species, although tulip, chestnut, beech, elm, and basswood are also used. A large number of imported woods that have attractive color or figure are utilized. Altogether some 60 species are used, with a consumption of nearly 1,500,-

000,000 board feet. Veneers are increasing in importance, for they can be used to cover cheaper and less attractive woods

Railroad Cars.—About 1,000,000,000 board feet of lumber are used each year in the building of the various kinds of railroad cars At least 40 different species of wood are used, although yellow pine and Douglas fir furnish the greater part. Oak, maple, hemlock, cypress, and several ornamental woods are also important The sills, brake beams, posts, etc.; the sides and roofing; and the interior finish require different kinds of woods.

Vehicles.—The manufacture of vehicles has always been an important industry. The use of wood increased in magnitude in the early days of the automobile industry, but has fallen off since metal has so extensively replaced wood in that industry. The annual consumption of wood in vehicle construction is still about 1,000,000,000 board feet Maple, red gum, and oak supply about half the amount. The different parts of vehicles have their own special requirements. The bodies must be light and stiff, while the running parts require toughness and elasticity. Hickory, elm, ash, oak, locust, and birch are generally employed for wheels. Large quantities of softwoods are used by automobile manufacturers for crating purposes.

Other Industries.—The following list of products of other woodworking industries, arranged approximately in order of importance, will serve to give an idea of the extensive uses of wood in this country: agricultural implements, caskets and coffins, refrigerators and kitchen cabinets, ship and boat building, matches, woodenware and novelties, musical instruments, tanks and silos, signs and supplies, professional and scientific instruments, electrical machinery and apparatus, machine construction, toys, laundry appliances, handles, supplies for dairymen, poultrymen and beekeepers, tobacco boxes, patterns and flasks, sporting and athletic goods, boot and shoe findings, shade and map rollers, brooms and carpet sweepers, picture frames and moldings, motion-picture and theatrical scenery, brushes, plumber's woodwork, shuttles, spools and bobbins, trunks and valises, sewing machines, pumps, wood pipe and conduits, airplanes, toothpicks, printing materials, playground equipment, dowels, clocks, paving materials, saddles and harness, gates and fencing, butcher blocks and skewers, bungs and faucets, firearms, scales, elevators, whips, canes and umbrellas, tobacco pipes, and artificial limbs.

Posts

It is difficult to estimate the consumption of wood for fence posts since such a large number are cut and used locally. The total, however, must be about 900,000,000. Fence posts are used chiefly on farms and along roads and railroad right of ways. The old rail fences have almost disappeared. Posts are usually cut 7 ft. in length and from 4 to 6 in. in thickness. They are

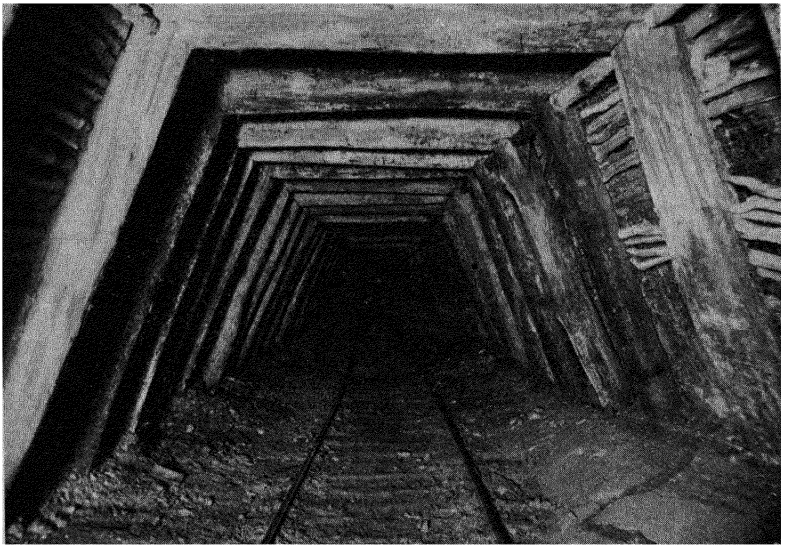


Fig. 32.—Mine timbers. A stretch of gangway in a Pennsylvania mine. (*Photo by U.S. Forest Service.*)

used in the round or are split. Strength, light weight, and durability in the soil and weather are the main requirements. A great variety of woods are utilized, principally redwood, cedar, chestnut, oak, tamarack, ash, and cypress. In order to increase their durability, fence posts are usually treated with preservatives.

Mine Timbers

A large amount of wood is used in mines for shafts and for the various types of supporting structures (Fig. 32), such as props, caps, and collars. Durability is particularly important for the wood is used in an environment especially favorable for the agencies of decay. Almost any kind of wood is likely

to be used, however, for, at best, mine timbers are only for temporary use; frequent replacements are necessary as the result of breakage, wear, and decay. Oak, pine, chestnut, tamarack, maple, beech, hemlock, and Douglas fir are among the more important species. Very little mine timber enters the trade, for most of the supply is cut locally from whatever wood is available.

Poles and Piling

Over 3,000,000 poles are used each year for telephone, telegraph, electricity, and power-transmission lines About the same number of piles are used for harbor work of various kinds and bridge, trestle, and wharf construction

Poles are used in the round, and, as they are likely to decay at the ground level, only woods with a durable sapwood are used. Even these woods are treated with preservatives Other requirements are strength, light weight, and accessibility. The shape is also important. Cylindrical tapering poles with large butts are the most desirable. Piles, in addition to the above requirements, must be able to withstand heavy top loads and must be capable of being driven.

Cedars, especially the western red and northern white cedar, are used to the greatest extent Other favored species include the chestnut, oak, southern pine, cypress, Douglas fir, redwood, larch, elm, and locust.

Cooperage

The cooperage industry, which comprises the manufacture of wooden containers bound together with hoops of wood, is a very old industry, dating back to Biblical and Roman times. There are two classes of products: *slack cooperage*, for holding dry substances; and *tight cooperage*, for holding liquids.

Slack Cooperage.—This type of cooperage includes a great variety of tubs, barrels, casks, pails, buckets, kegs, churns, and other containers. They are used to transport vegetables, fruit, flour, sugar, cement, crockery, glassware, and a host of other materials. A single barrel usually consists of 15 staves, one set of heading, and six hoops. These various parts may be manufactured in different factories and even in different regions. There are many grades of slack cooperage ranging from flour

and sugar barrels, with tongued and grooved staves, to the loose-fitting and cheaply constructed cement barrels.

Wood for use in slack cooperage must be cheap, light, easy to work, elastic, and free from warping and twisting. Otherwise any sort of wood is permissible. Limbs, tops, defective logs, and other forms of waste lumber can be utilized. Veneers are being used to a considerable extent. Staves and heads are usually made from red gum, pine, elm, beech, maple, oak, Douglas fir,



FIG. 33.—White oak staves in Alabama ready for shipment. (*Photo by U.S. Forest Service.*)

and ash. Hoops are made chiefly from elm, although hickory and ash are occasionally used. Metal hoops are also utilized.

Tight Cooperage.—Barrels and kegs that are to be used as containers for oil, beer, wine, and other liquids are more carefully constructed. Woods which will impart no odor or taste to the liquids and which are impermeable are essential. White oak has long been the outstanding wood used (Fig. 33), especially when the liquids are to remain in the barrels for a long time. Red oak, red gum, and cypress are also utilized. The finished product is usually treated on the inside with paraffin to insure that no leakage will occur.

CROSS TIES

During the last 50 years there has been a great demand for railroad ties, the number used increasing from 35,000,000 in

1880 to 142,000,000 in 1910. This was the period of expansion for both steam and electric roads. More recently there has been a reduction in the consumption of ties, due in part to a lessened demand and in part to the longer life of the ties as a result of preservative treatment. The number of ties used each year will always be considerable, considering that there are several billion ties in use and that the average life of a tie is only five years.

Ties are usually hand hewn from a seasoned wood. Strength, durability in the soil, and the ability to resist impact, crushing, and spike pulling are essential. Treated ties are fully as serviceable as those made from naturally durable woods. Seventy per cent of the ties are made from oak, southern pine, and Douglas fir. Other species used include cypress, red gum, cedar, chestnut, maple, tamarack, and hemlock. Douglas fir ties are often sawed

Veneers

Veneers are thin slices or sheets of wood. Although they can be cut as thin as $\frac{1}{200}$ in., the commercial product is usually about $\frac{1}{20}$ in. thick. Veneers do not represent a new development in the utilization of wood, for they were known to the Romans Their use in this country was retarded for many years because wood was so abundant and so cheap. In recent years, however, a large demand for veneers has arisen, due partly to their own inherent qualities, partly to the necessity of conserving the supply of valuable timber, and partly to the fact that wood can be used which otherwise would be wasted.

In making veneers, logs or pieces of wood are boiled and then cut with a knife. Although several processes are used, 90 per cent of veneers are cut by the *rotary process*. This involves turning a log on a lathe against a stationary knife, with the formation of a continuous sheet of veneer. This process is quite wasteful as a core from 6 to 10 in. in diameter is left. This core, however, can be used for fuel, boxes, crates, excelsior, and various industries. The figure in this type of veneer is not very striking, since the sheet is cut parallel to the annual rings. In the *slicing process* logs are quartersawed and consequently show a more attractive figure. The logs are first quartered and then sliced with a stationary knife, thus yielding separate sheets. This is the least wasteful process and is used for many of the imported

woods. In the *sawing process* quartered logs are cut with a circular saw. Although the resulting veneers are quite thick and although the process is a rather wasteful one, the most valuable woods are sawed because the fibers are but little torn and the material can be more readily worked up.

At first veneers were used only in connection with furniture and cabinetwork to cover up inferior woods, and they were made from mahogany, walnut, and other woods with a beautiful color, grain, and figure. Now many species are used and the veneers are utilized in the manufacture of boxes, baskets, cooperage, door panels, trunks, mirrors, musical instruments, and many other articles. Veneers make possible maximum strength with minimum weight. Any wood is suitable which comes in large sizes, has a symmetrical grain and figure and few defects, and is inexpensive Some 37 native species are used, together with about a dozen imported woods. Red gum is the most valuable native wood for the best veneers, while yellow pine is used for the cheaper grades. Other important species include maple, tulip, cottonwood, tupelo, oak, Douglas fir, birch, spruce, walnut, cedar, and basswood.

Plywood.—A recent extensive development in connection with veneers has been the utilization of "built up" stock, or *plywood.* This involves the gluing together of from three to seven thin sheets of wood. The successive layers have the grain running in opposite directions, so that the finished product is very strong and is much less likely to crack, warp, or twist. It is also light and inexpensive. One common type of plywood has a $\frac{3}{8}$-in. core of poplar with $\frac{1}{10}$-in birch veneers on either side. Plywood is used for doors, panels, airplanes, furniture, trunks, and interior finish The softer woods are generally utilized, for they can be glued more easily.

Shingles and Shakes

Shingles are thin pieces of wood used to protect the roofs and sides of buildings from the weather. Until recently they were made by hand by riving bolts of wood and shaving off the shingles with a drawing knife. Shingles are now chiefly machine made (Fig. 34) and some are sawed. Shingle wood must be durable, light in weight, easy to split, and able to hold nails without loosening, and it must not warp. Straight, even-grained

woods are best. The durability of shingles is increased by treating them with preservatives.

The most outstanding shingle wood is cedar. The western red, northern white, and southern white cedars are all used extensively. Shingles are also made from redwood and cypress. The output of shingles reached its peak in 1909 when 15,000,000,000 were

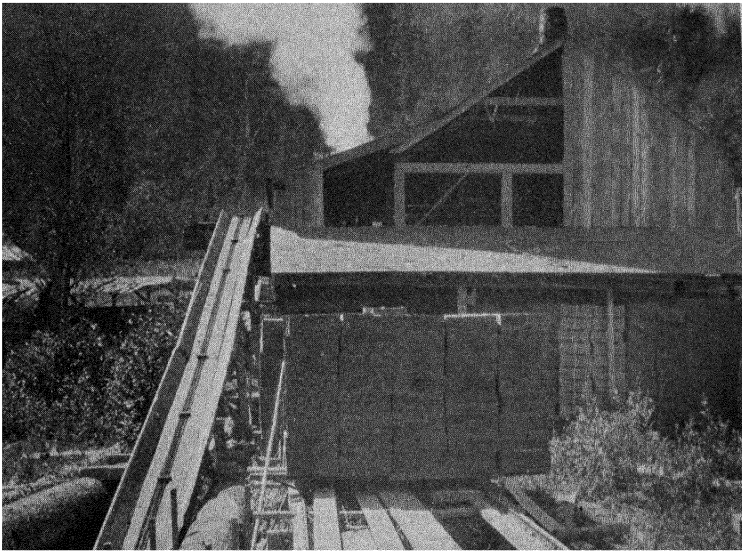


FIG. 34.—A shingle mill in the Olympic Forest, Washington (*Photo by U.S. Forest Service*)

produced. Since that time the industry has suffered from the many substitutes.

Shakes are split shingles, and naturally are much thicker. They are used in the East chiefly in the more remote regions, such as the southern Appalachians. In the West shakes were in common use until sawed shingles came on the market. They are still frequently used for the bottoms of trays for drying fruit. Western red cedar, sugar pine, and redwood are the principal sources.

EXCELSIOR

Excelsior consists of thin curled strands or shreds of wood, and is made by placing wood on frames and pressing it against

rapidly moving knives or steel teeth. This material was first known as *wood fiber*, and "excelsior" was later introduced as a trade name. Excelsior is light and elastic and makes an excellent material for packing and shipping glassware and other breakable articles. It is resilient and free from dust and dirt, and so can be used for stuffing mattresses and upholstery. A very fine grade of excelsior, known as *wood wool*, is used in filters and in the manufacture of rugs and matting.

The production and use of excelsior have increased greatly in recent years. Almost any wood that is light in weight and color,

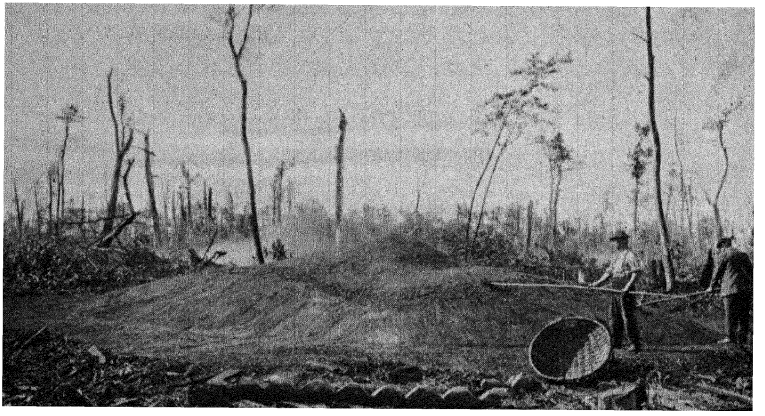


FIG. 35.—Cleaning the dust in a charcoal pit in Pennsylvania. (*Courtesy of S. J. Record.*)

odorless, and free from resins or gums can be used. Basswood, which is very soft and springy, is the best material. Cottonwood and the other poplars and yellow pine are used to a great extent. Other woods include buckeye, tulip, birch, spruce, maple, white pine, and red gum. Wood waste from the other industries is also used. It is estimated that a cord of wood yields about 1500 lb. of excelsior.

CHARCOAL AND WOOD DISTILLATION

Charcoal

The heating of wood in order to convert it into carbon or charcoal is a practice as old as civilization. Charcoal is still a valu-

able fuel, since it has twice the heating power of wood and burns without flame or smoke. It is extensively used in many European countries, particularly where forests are abundant, and it is the chief domestic fuel in most tropical countries. Charcoal is also used in medicine, as a reducing element in the iron and steel industry, and in the manufacture of chemicals, gunpowder, and explosives. The best yields of charcoal are obtained from the denser hardwoods, such as beech, maple, birch, oak, and hickory. Willow charcoal is especially desirable for explosives. The conversion of wood into charcoal was formerly carried on in open-air pits (Fig. 35) by a process of partial combustion. This method was extremely wasteful as all the volatile material contained in the wood was lost. Today charcoal burning has been replaced by wood distillation, and the valuable gases are recovered.

Wood Distillation

Wood distillation is important, not only in rendering available the volatile wood elements, but as a factor in forest conservation. One of the chief sources of wood for distillation purposes is the waste left by lumbering operations, sawmills, and planing mills. There are two distinct types of wood distillation.

Hardwood Distillation.—This process utilizes the denser and heavier hardwoods and has been carried on in the United States for over 100 years. The products are wood alcohol, acetate of lime, charcoal, wood tar, and wood gas. The wood is heated in large oven retorts (Fig. 36) where it is converted into charcoal. The gases given off are condensed as pyroligneous acid. Tar and oils are allowed to settle out, and the remaining acid is passed through a series of stills where more tar and oils are removed. Eventually slaked lime is added and in a final distillation wood alcohol passes off; acetate of lime is left as a residue. The average yield per cord is 45 to 52 bu. of charcoal, 180 to 225 lb. of acetate of lime, 8 to 10 gal. of wood alcohol, 25 gal. of wood tar, and 11,500 cu. ft. of wood gas. Tropical hardwoods afford a vast and untouched source of wood for distillation.

Acetate of lime is used chiefly in the manufacture of acetic acid, which has wide applications in the textile, paint, and leather industries; and acetone, which is used in the manufacture of explosives and chloroform. Wood alcohol finds its greatest use as a solvent, especially in the paint and varnish industry. It is also

used in making aniline dyes, formaldehyde, and photographic films. Methyl alcohol, which is refined wood alcohol, is used as a fuel, illuminant, denaturant, and ingredient in countless medical, chemical, and other industrial preparations. Wood tar and gas are used chiefly as fuel for the ovens.

Softwood Distillation.—This is a more recent development, which utilizes resinous woods, chiefly southern yellow pine. Several methods are used. In *destructive distillation* the wood is

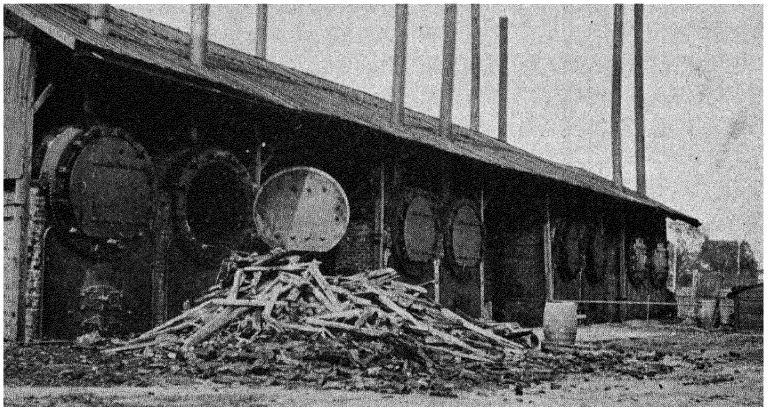


FIG. 36.—Wood distillation retorts in Wilmington, N.C. (*Photo by U.S. Forest Service.*)

heated in ovens, and the products are charcoal, turpentine, oils, tar, and wood gas. In *steam distillation,* which is more extensively used in Russia, Finland, and Sweden than in the United States, turpentine and oils are extracted by steaming chips or sawdust in retorts. In the *extraction process* solvents are added which remove the rosin, as well as the other products. Both the turpentine and the rosin obtained by distillation are inferior to the products of the naval-stores industry to be discussed in a later chapter. The tar and oils obtained in softwood distillation are used in making preservatives, such as creosote, stains, and many other products.

Processes have been developed recently which convert wood into ethyl alcohol by hydrolysis with sulphuric acid. If this operation can be carried out profitably on a commercial scale,

it has great possibilities, for ethyl alcohol is one of the best substitutes for gasoline in internal-combustion engines.

Other Uses of Wood

The use of wood as a raw material for the paper industry and as a source of tanning and dye materials is discussed elsewhere.

CORK

Cork is a forest product of great antiquity, its use dating back at least as far as Greek and Roman times. (It is obtained commercially for the most part from the cork oak) (*Quercus suber*), a tree native to the Mediterranean region. This is a species from 20 to 60 ft. in height and 4 ft. in diameter, with a short trunk and densely spreading crown. The evergreen leaves resemble those of holly, but are spongy and velvety. The acorns serve as a food for swine. The cork oak is found from the Atlantic to Asia Minor, and is especially abundant in Portugal, Spain, Algeria, Tunisia, southern France, Morocco, and Corsica. About 3,764,000 acres of cork forests occur, over a million of which are found in Algeria. The tree thrives best on rocky siliceous soil on the lower slopes of the mountains.

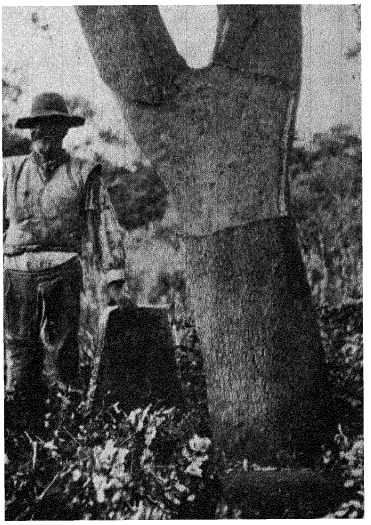


Fig. 37.—A cork gatherer in Gibraltar, Spain. (*Photo by U.S. Forest Service.*)

Cork consists of the outer bark of the tree. This can be removed without injury to the tree, and, provided the inner bark is not damaged, it is renewed, new layers being formed each year. The operation consists of making vertical and horizontal cuts with hatchets or saws, and then prying off large pieces of the bark (Fig. 37). Great care is taken not to injure the inner bark, which would prevent the formation of new bark and might even endanger the life of the tree. The rich dark-red

color of the exposed areas is one of the characteristic sights in a cork forest. The stripping is usually carried on in midsummer when weather conditions are most favorable.

The bark of both the trunk and larger branches is usually utilized, although in some countries the cutting area is restricted to the first 6 ft. of the trunk. Cork is first removed when the trees are about 20 years old. This first yield, which is known as virgin cork, is very rough and coarse and of little value. Subsequent strippings occur every nine years. The second yield is better, but the best quality of cork is not obtained until the third cutting and thereafter. The trees live for 100 to 500 years, and have an average yield of 40 to 500 lb. per tree. The best grade of cork consists of inch-thick layers obtained from young vigorous trees.

After stripping, the pieces of cork are dried for several days and weighed and then shipped to some central point for further treatment. They are first boiled in large copper vats. This removes the sap and tannic acid, increases the volume and elasticity, and flattens the pieces. It also loosens the outermost layer, which is scraped off by hand. The rough edges are then trimmed off, and the flat pieces are sorted and baled.

Cork possesses many properties that make it very valuable in industry. In spite of its bulk it is very light and exceedingly buoyant, owing to the fact that it is composed entirely of dead watertight cells. It can be readily compressed and is very resilient. Even after 10 years of use cork stoppers will recover 75 per cent of the original volume. It is durable, a low conductor of heat, and is resistant to the passage of moisture and liquids. It also absorbs sounds and vibration and has certain frictional properties.

Uses of Cork

Cork is used for many purposes and for the manufacture of a great variety of products. In some cases the natural cork is utilized, and in others a cork composition, made of coarse or finely ground cork and other substances. Corkboard is used in heat and cold insulation for houses, cold-storage plants, refrigerators, and even hats for use in the tropics. It serves as a means of improving the acoustics of rooms and rendering them soundproof.

Several types of floor covering are made from cork, including linoleum, cork tiles, and linotiles. *Linoleum* is prepared from scrap cork, linseed oil, and burlap. The oil is boiled and allowed to solidify by dripping on pieces of cloth. The solidified oil is ground up and melted with resins and gums. This mixture is cooled and hardened, and after several days of "curing" is mixed with cork, which has been ground as fine as dust, and dry color pigments. This mixture is pressed into burlap cloth with hydraulic presses. The linoleum is then seasoned in ovens and finished by giving it a protective surface of nitrocellulose lacquer. *Linotiles* are individual tiles made from ground cork and linseed oil, but much thicker and denser than linoleum, *Cork tiles* are made from natural cork by baking in molds under great pressure.

Other articles made from cork include: stoppers, which are cut by hand or machine; crowns, for use inside the metal tops for bottles; carburetor floats and gaskets for automobiles; toes, counters, and inner soles for shoes; handles for golf clubs, penholders, fishing rods, and other articles; mooring buoys, floats, life preservers, and surf balls; baseball centers; decoys; mats; and many other products.

Over 500,000,000 lb. of cork are produced each year, chiefly in Spain, Portugal, and Algeria The United States imports about 1,000,000 lb. and Germany, Great Britain, and Russia are also large consumers.

CHAPTER IV

FOREST RESOURCES

DISTRIBUTION OF FOREST LANDS

Climatic conditions, in some parts at least, of all the continents are favorable for the development of forests. Although our knowledge concerning the exact nature and distribution of these forests is still incomplete, it is possible to estimate roughly the amount of forest land in the world as about 7,500,000,000 acres, or 22½ per cent of the earth's surface. These forest lands are distributed on the various continents as follows: Asia, 28 per cent; South America, 28 per cent; North America, 19.3 per cent; Africa, 10.6 per cent; Europe, 10.3 per cent; Australia and Oceania, 3.8 per cent. In many countries forests were originally much more abundant than they are at the present time.

The softwoods or conifers occupy 35.4 per cent of the total forest area, occurring in pure stands or mixed with hardwoods. They are especially characteristic of the colder areas, about 95 per cent occurring in the north temperate zone. When they are found in warmer regions, conifers are restricted to the higher altitudes. In the case of the hardwoods, a distinction is usually made between temperate and tropical hardwoods. The former occupy 16 per cent and the latter 35 4 per cent of the total forest area. As in the case of the conifers, most of the temperate hardwoods (89 per cent) are found in the north temperate zone. It is of interest to note that three-quarters of the world's population lives in this area, and consumes nearly 90 per cent of all the wood used. The fact that both the softwoods necessary for general construction and the hardwoods have been readily available throughout this area has been of great economic importance. It has been only recently, as a result of the depletion of the native forests, that attention has been turned to the almost untouched tropical forests, save as a source of ornamental woods, dyewoods, and similar products.

FORESTS OF NORTH AMERICA

Forests occupy about 26 8 per cent of the land area of North America, with conifers comprising 72.4 per cent, temperate hardwoods 20.1 per cent, and tropical hardwoods 7.5 per cent of the forests. The northern part of the continent—Alaska, Canada, Newfoundland—is predominantly coniferous, with 93 per cent of the softwoods and 7 per cent of temperate hardwoods. The United States has 62 per cent conifers and 38 per cent temperate hardwoods; Mexico has 47 per cent conifers, 34 per cent temperate hardwoods, and 19 per cent tropical hardwoods. In Central America tropical hardwoods account for 75 per cent and conifers 25 per cent of the total The West Indies have an even higher percentage of tropical hardwoods (87 per cent), with 13 per cent of conifers.

In the United States at the present time there are about 469,000,000 acres of woodland, comprising 24.7 per cent of the total land area. Of this amount about five-sixths is capable of producing lumber on a commercial scale The present forest area is only a little over half that of the original forests that existed at the time of the first English settlements three centuries ago.

Forest Areas of North America

The forests of North America are found in at least six well-defined areas (Fig. 38): (1) the northern coniferous forest; (2) the eastern deciduous forest; (3) the southeastern coniferous forest; (4) the Rocky Mountain forests; (5) the Pacific Coast forests; and (6) the tropical and subtropical forests.

Northern Coniferous Forest.—This great evergreen forest extends across the continent from Newfoundland and Labrador to the lower Hudson Bay region and Alaska, south of the treeless arctic tundra. The chief trees are white spruce, black spruce, balsam fir, and larch, with some paper birch, aspen, and balsam poplar. From Nova Scotia and northern New England to Minnesota, and southward along the summits of the Appalachians, there exists a transitional region between the coniferous forest and the eastern deciduous forest, with species of both these areas intermingled. Prominent trees of this so-called "northern hardwood region" include the white pine, red spruce, white

cedar, beech, sugar maple, hemlock, yellow birch, and locally the red pine and jack pine.

Eastern Deciduous Forest.—This forest, one of the oldest on the continent, covers most of the eastern and central part of the



FIG. 38.—The forest formations of North America. North of the northern evergreen forest is the tundra formation. On the unshaded areas south of it are the prairie, plains, and desert formations (*Reproduced by permission from Transeau, General Botany, World Book Company, Yonkers-on-Hudson, N.Y.*)

United States. It attains its best development in the lower Ohio valley and on the slopes of the southern Appalachians. It extends as far north as Ontario and southern Quebec. The

more important trees are the oaks, hickories, chestnut, tulip, black walnut, basswood, ash, and elm. Toward its northern limits, as we have just seen, the beech and maple become prominent, intermingled with various conifers. Similarly toward its southern and southwestern limits the oaks and hickories often occur with many of the pines that characterize the southeastern coniferous forest. Westward the deciduous forest becomes gradually restricted to the river valleys of the prairie region.

Southeastern Coniferous Forest.—This forest is found along the sandy Atlantic coastal plain from Virginia to Texas. The various pines, principally longleaf, shortleaf, loblolly, and slash pines, occur on the uplands; in lower ground are found red gum, tupelo, live oak, and magnolia. Southern white cedar and cypress occur in the swamps.

Rocky Mountain Forest.—Like all the forest areas of western America, the Rocky Mountain forest is made up almost entirely of coniferous species. The area extends from northern British Columbia southward across the United States and Mexico, and even into Central America. Naturally in so large an area there are many differences in the nature of the forest due to latitude and altitude. Western yellow pine is the most characteristic species. Others include the lodgepole pine, Douglas fir, white fir, and western larch, with Engelmann spruce and alpine fir at the higher elevations. In northern Idaho and adjacent Montana a forest occurs which is quite similar to some of those on the Pacific coast, with western red cedar, western hemlock, and western white pine as the chief species.

Pacific Coast Forests.—Within the Pacific coast region there are several distinct forest areas. Along the coast from Alaska south to Washington, Sitka spruce is the chief species. In southern British Columbia, the Puget Sound region, and eastern Oregon and Washington as far east as the summits of the Cascade Range there is situated one of the most magnificent conifer forests in the world. Few, if any others, can surpass it in density of the stand and the size of the trees, which reach a height of 200 to 250 ft. and a diameter of 8 to 15 ft. The mild winters, due to the nearness of the ocean, and the very great precipitation, about 100 in., are in part responsible for the development of this forest. Douglas fir is the dominating species, and with it are associated western hemlock, western cedar, Sitka spruce, and

several firs. This region is the location of the largest lumbering operations in the country at the present time.

From Oregon south to San Francisco Bay the forests along the Coast Range are dominated by the redwoods, the tallest of all the conifers. This region has been exploited for many years and much of the timber has been cut and the land given over to agriculture.

East of the Cascade Range the forests tend to merge with those of the Rocky Mountains. The principal trees are western yellow pine, Douglas fir, western larch, lodgepole pine, and locally western white pine, Engelmann spruce, and alpine fir. This forest also extends southward along the Sierra Nevadas in California. Here western yellow pine, sugar pine, incense cedar, Douglas fir, and white fir are common with red fir at the higher altitudes. The Big Trees are found locally along the lower slopes of the Sierras.

Tropical Forest.—Subtropical conditions are found in southern Florida, but none of the trees are of commercial importance. True tropical forests are found in the Mexican lowlands, on the eastern slopes of Central America, and in the West Indies. Most of the original forest in the latter two regions has been destroyed as a result of migratory agriculture and has been replaced by the dense, almost impenetrable tropical jungle. The more important tropical species of North America will be considered together with those of South America.

The Principal Woods of Temperate North America

In North America there occur over 500 species of woody plants, exclusive of tropical species. About a hundred of these are of commercial importance. The most prominent of these will be considered briefly.

SOFTWOODS

Cedar

The cedars of commerce all have a fragrant, light, soft wood which is even grained and resistant to decay. The chief use of the wood is in millwork and the manufacture of instruments, woodenware, caskets, boats, and laundry appliances. Commercial cedar comprises seven different species:

The Port Orford cedar (*Chamaecyparis Lawsoniana*), found in Oregon and California, is the hardest of all the cedars. It yields a strong, heavy, stiff timber which takes a good polish. The wood is used for boats, furniture, millwork, matches, floors, interior finish, and posts. It is exported to England for use in airplanes.

The Alaska cedar (*Chamaecyparis nootkatensis*) ranges from Alaska to Oregon along the Pacific coast The light, stiff, hard, strong wood is easy to work and durable It is used for boats, shingles, fences, and interior finish.

The southern white cedar (*Chamaecyparis thyoides*) is a smaller tree found in the Atlantic coast states The wood is used for boats, shingles, posts, ties, and cooperage. In colonial days it was used for houses, but it is too light to support the weight of second stories.

The incense cedar (*Libocedrus decurrens*) of California and Oregon has a close-grained reddish wood of considerable value on the Pacific coast. It is used for building purposes, posts and piling, and to some extent for lead pencils.

The eastern red cedar (*Juniperus virginiana*) is one of the most characteristic trees of the eastern United States. The wood is very durable and is especially resistant to weather conditions It is used for poles, fence posts, crosstrees, ties, etc. The sapwood is white, and the heartwood a rich red and very fragrant The wood is soft, with a fine, even grain, and it can be whittled easily, so it constitutes the standard wood for lead pencils. Chests, cigar boxes, pails, panels, veneers, and interior finish are also made from it.

The northern white cedar or arbor vitae (*Thuja occidentalis*), a common tree of New England, the Lake States, and adjacent Canada, is one of the lightest of woods. It is soft and easily worked and is utilized for woodenware, canoe and boat building, shingles, fence posts, poles, tanks, and silos.

The western red cedar (*Thuja plicata*) of the northern Rocky Mountains and Pacific Northwest is the largest of the cedars, reaching a height of 150 ft. and a girth of 30 ft. The brownish-red, close, even-grained wood is very soft, but extremely durable. Four-fifths of the output is used for shingles Other uses include fences, poles, interior finish, cabinetwork, and cooperage. The coast Indians used this species for their totem poles and war

canoes, and also made ropes and textiles from the bast fibers of the inner bark.

Cypress

The bald cypress (*Taxodium distichum*), a characteristic tree of swamps along the Atlantic coast from Delaware to Texas and

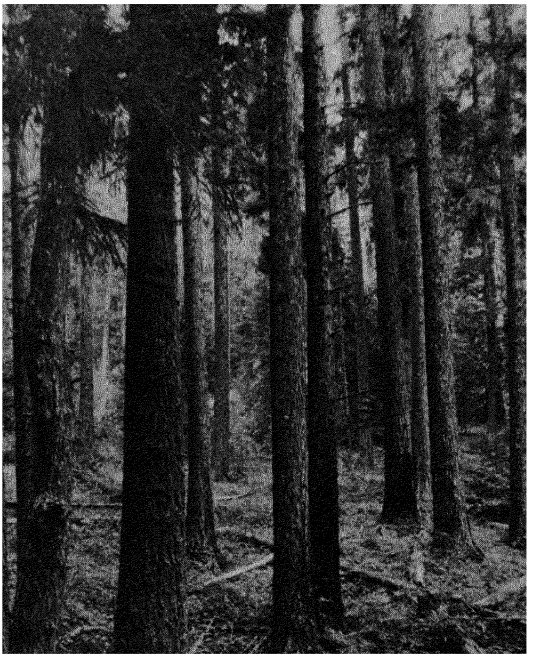


FIG. 39.—A stand of Douglas fir (*Pseudotsuga mucronata*) in the Siskiyou National Forest, Oregon. (*Photo by U.S. Forest Service.*)

in the lower Mississippi valley, is one of the strongest and heaviest of the softwoods. The tree reaches a height of from 80 to 140 ft. and a girth of from 5 to 12 ft. Conspicuous features are the "knees," conical outgrowths from the roots for purposes of aeration. Unlike most conifers, the cypress sheds its leaves. The wood is a rich red color with a distinct grain. It is soft and coarse and works well. Its chief utilization is in millwork for cabinet and interior-finish purposes. It is also used for shingles, ties, posts, sides of greenhouses, tanks and cisterns, and other

structures exposed to decay, for the wood is very durable and long lived. Boxes, boats, and cooperage are other products.

Douglas Fir

The Douglas fir (*Pseudotsuga mucronata*) is one of the two most important American woods at the present time, and more of it is available than any other species. The tree covers a wide range of territory in the northwestern United States and adjacent Canada. It is very large, reaching a height of 200 ft. or more and a diameter at the base of 8 to 10 ft. (Fig 39). The lowest branches are high up, so the trees are frequently used for masts, spars, and flagpoles. The size of the trunk also makes possible timbers of any length and size. The wood is resinous with a close, even, well-marked grain, and is of medium weight, strength, stiffness, and toughness. It is very durable and, when well seasoned, does not warp. Over 50 per cent of the Douglas fir cut is used in heavy construction. Other uses include piles, ties, paving blocks, airplanes, floors, and millwork.

Fir

The true firs are of comparatively little commercial importance. The wood is very light, soft, and brittle, and finds its greatest use in the manufacture of boxes and crates. Fir is also used in millwork and as a source of pulpwood. The most important species are the balsam fir (*Abies balsamea*) of the northern coniferous forest region and four western species, the lowland white fir (*A. grandis*), the noble fir (*A. nobilis*), the red fir (*A. magnifica*), and the white fir (*A. concolor*).

Hemlock

The eastern hemlock (*Tsuga canadensis*), one of the most characteristic trees (Fig. 40) of the northeastern transition forest, furnishes a cheap coarse lumber used chiefly for framing timbers, scantling, sheathing, laths, rafters, and other types of rough construction. Other uses include pulp, ties, boxes, and plank walks. The wood is coarse grained and splintery, but is very strong, tough, stiff, and easily worked. The bark has long been used as a tanning material.

The western hemlocks (*Tsuga heterophylla* and *T. Mertensiana*) are larger trees and furnish a superior wood, which is heavier,

stronger, stiffer, and more suitable for heavy construction. Other uses are similar to those of the eastern hemlock. These trees are the most important sources of pulpwood in the Northwest.

Larch

The eastern larch or tamarack (*Larix laricina*) and the western larch (*L. occidentalis*) furnish the larch wood of commerce.



FIG. 40.—A pure stand of hemlock (*Tsuga canadensis*) in the Hearts Content area, Pennsylvania. (*Photo by U.S. Forest Service.*)

The former species is found in the northeastern United States and across Canada, while the latter, a larger tree, grows chiefly in Montana, Idaho, and Washington. Larch is one of the heaviest, strongest, and toughest of the softwoods and finds its chief use in furnishing heavy timbers for general building construction. Because of its durability larch is used for fences, posts, poles, ties, and paving blocks. The naturally curving lower parts of the trunk furnish ideal material for boat "knees," ribs, and other forms of ship timber. Larch is also used for planing-mill products, tanks, and boxes.

Pine

Pine has always been one of the most important of the commercial woods and today constitutes about one-half of the total lumber supply. The wood is obtained from several different species, belonging to either the soft-pine or the hard-pine group.

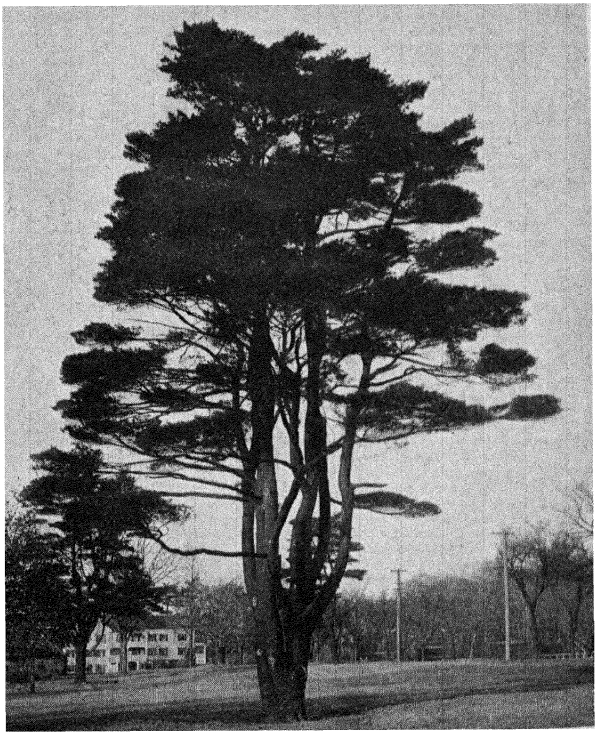


FIG. 41.—A white pine (*Pinus Strobus*), showing the characteristic habit. (*Photo by E. H. Wilson, courtesy of the Arnold Arboretum.*)

Although 28 species are of some value, only eight are outstanding. The *soft or white pines* have a straight-grained soft wood that is comparatively free from resin and easy to work. It is used for rough carpentry work, cabinetwork, patterns, cooperage, toys, crates, and boxes. The *hard or yellow pines* have a resinous, heavy, hard, strong, and durable wood, which finds its greatest use in buildings, bridges, ships, and other types of heavy con-

struction. Because of its durability yellow pine is much used for floors, stairs, planks, and beams.

White Pines.—The northern white pine (*Pinus Strobus*) (Fig. 41) is one of the most valuable timber trees of the world. It was formerly used more than any other species, both for domestic consumption and for the export trade. So much of this



FIG. 42.—The bark, leaves, and fruit of the southern yellow or longleaf pine (*Pinus palustris*). (*Photo by U.S. Forest Service.*)

wood has been cut that today the white pine has fallen to sixth place in importance. The tree is found in the northeastern United States and adjacent Canada, and along the Appalachian mountains to Georgia. The best stands today are found in Michigan, Wisconsin, and Minnesota. It is a conspicuous member of the forest flora in this region, often attaining a height of from 100 to 200 ft. and a diameter of 3 to 9 ft. The wood is very light and easy to work as it is one of the softest of timbers. It is also very durable. Houses constructed in colonial days are

still in good condition. The sapwood is white and the heartwood a pinkish brown, with a fine, even grain and lustrous surface. At the present time white pine is used chiefly for doors, window sashes, pattern making, cabinetwork, boxes, and matches. Several other species with a similar wood and uses are classified as white pine by the lumber trade. These include the western white pine (*P. monticola*), the sugar pine (*P. Lambertiana*), and the lodgepole pine (*P. contorta*).

Yellow Pines.—These are a much more heterogeneous group and, although often classed together, each species has a distinctive wood. The southern yellow or longleaf pine (*Pinus palustris*) (Fig. 42) is one of the two most important timber trees of the United States at the present time. It is found in the Southeastern states from North Carolina to Texas. The wood has a fine, smooth, compact grain and is the heaviest, hardest, strongest, stiffest, and toughest of the softwoods. It is very durable and capable of bearing great weights. Its chief use, consequently, is for beams, joists, and other timbers for heavy construction, and for wharves, bridges, ships, cars, and railroad ties. Some yellow pine is used for millwork and boxes. The wood is very resinous and the tree is the chief source of the naval-stores industry to be discussed later. It is also an important pulpwood. Associated with the yellow pine in the southern forests, and often classified with it, are the shortleaf pine (*P. echinata*), the slash pine (*P. caribaea*), and the loblolly pine (*P. Taeda*).

Other important hard pines are the western yellow pine (*Pinus ponderosa*) and the red or Norway pine (*P. resinosa*) of the Eastern states.

Redwood

The redwood (*Sequoia sempervirens*), restricted to the Coast Range of northern California, is one of the largest trees in the world, reaching a height of from 200 to 300 ft. and a diameter of from 8 to 22 ft. Its only rival is the famous Big Tree of California (*S. gigantea*) (Fig. 43) whose dimensions and age, the latter estimated at 3600 years, are equalled by no other living organism. The wood of the Big Tree is of little commercial value, so these giants of the forest have been spared destruction. The redwood, however, has been extensively exploited in recent years, and only the strenuous efforts of conservationists and nature lovers

have made possible the setting aside of a few stands, in which this magnificent species will be protected for all time.

The wood is fine and straight-grained, strong, light, and very soft. The sapwood is pale in color, while the heartwood is a rich dull red. The cinnamon-brown bark, which is often 1 ft. in



FIG. 43.—*Sequoia gigantea*. The General Sherman Tree, shown here, is believed to be the largest and possibly the oldest tree in the world. (*Photo by U.S. Forest Service.*)

thickness, is very striking. Redwood does not warp or shrink readily and is very durable, particularly after seasoning. It is used for general construction purposes, shingles and siding, tanks, coffins, silos, posts, water pipes, ties, furniture, cabinetwork, and interior finish.

Spruce

The several species of spruce have a light, soft, compact, straight-grained wood which is stiff, strong, easy to work, and comparatively free from resin. Spruce has increased in importance as white pine has become scarce. The chief uses are for

pulpwood, light construction, boxes, millwork, and cooperage, and as Christmas trees. The wood is resonant and so is much used for sounding boards of pianos and the bodies of violins and similar instruments. The principal species is the white spruce (*Picea glauca*), one of the most characteristic trees of the great coniferous forest that stretches from the northeastern United States to Labrador and across the continent to Alaska. Other eastern species are the red spruce (*P. rubens*) and the black spruce (*P. mariana*), both of which have a more restricted distribution The most important western species is the Sitka or tideland spruce (*P. sitchensis*) This large tree, which reaches a height of from 200 to 300 ft., grows along the coast from Alaska to northern California. In addition to the uses already mentioned for spruce, Sitka spruce is used for boats, oars, and other products that require a light, strong, and elastic wood It was formerly used extensively in airplane construction. Engelmann spruce (*P. Engelmanni*), found in the Rocky Mountain and Cascade Range region from Canada to Arizona and New Mexico, is also of importance.

HARDWOODS

Ash

Ash wood is strong, elastic, tough, hard, stiff, and light in weight. It is light reddish brown in color, easy to split, and hard to nail. It is often beautifully figured and is capable of a high polish. The characteristics of ash adapt it to a wide range of uses other than structural. Among the articles made from ash may be mentioned handles, oars, bats, tennis rackets, rods, cues, clothespins, toys, barrels, and baskets It is also used for carriages, cars, boats, farm implements, furniture, cooperage, refrigerators, and interior finish. The most important species is the white ash (*Fraxinus americana*), a tree of the eastern deciduous forest. Other prominent species include the red ash (*F. pennsylvanica*) and its variety, the green ash (var. *lanceolata*); the blue ash (*F. quadrangulata*); the black ash (*F. nigra*) - all eastern species; and the Oregon ash (*F. oregona*) of the West coast.

Basswood

The basswood or linden (*Tilia glabra*) is a tree primarily of the eastern deciduous forest. It is a large species reaching a height

of 80 ft. The wood is light-colored and straight-grained with a smooth uniform texture. It is the lightest, softest, weakest, and least tough of the more important hardwoods. However, because of its color, even grain, and extreme ease of working it is widely used. Its uses include boxes and crates, millwork,

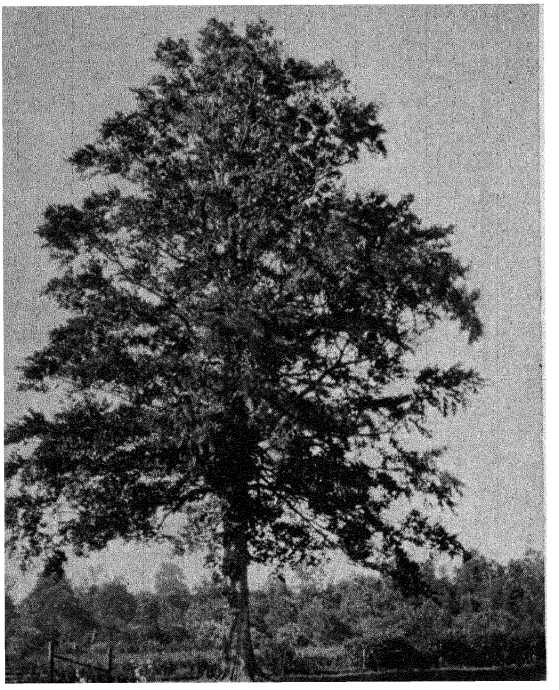


FIG. 44.—An American beech (*Fagus grandifolia*) growing in the open in Tennessee. This tree is 110 ft. high and has a diameter at breast height of 50 in. (*Photo by U.S. Forest Service.*)

woodenware and novelties, furniture, trunks, picture frames, carriage bodies, cooperage, pulp, charcoal, and excelsior.

Beech

The beech (*Fagus grandifolia*) (Fig. 44) is one of the three most characteristic trees of the northeastern transition forest. The fine-grained pinkish-brown wood (Fig. 45) is moderately hard, strong, and heavy, and has a wide range of usefulness. Beech is extensively used for boxes and crates because it does not impart any taste or odor. Flooring, interior finish, furniture

and fixtures, tool handles, woodenware, laundry appliances, clothespins, wagon stock, shoe lasts, and ties are among the other products made from beech The wood is also used for fuel, charcoal, and wood-distillation purposes.

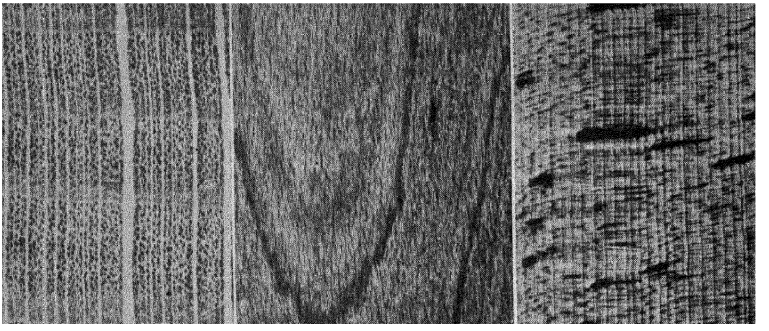
Birch

Birch wood (Fig. 45) is hard, heavy, strong, and tough, with a fine wavy grain that is often beautifully figured and capable of a high polish. It is often stained and finished to imitate cherry or mahogany. The yellow birch (*Betula lutea*), which ranges from New England and the Lake States to Georgia, and the black birch (*B. lenta*), which has a more restricted distribution, furnish most of the wood used for furniture, doors, window frames, floors, and other forms of millwork. Other articles made from birch include: handles, clothespins, shoe pegs and lasts, wheel hubs, woodenware, boxes and baskets, dowels, yokes, and spools.

The white or paper birch (*Betula papyrifera*) is a more northern tree ranging from the northeastern United States across Canada. The wood, which is very strong and elastic with a fine uniform texture, is used chiefly for spools, toothpicks, boxes, handles, dowels, bobbins, and shoe lasts and pegs, and in turnery. The bark, which peels off in characteristic layers, finds a use in the manufacture of canoes and fancy articles of various kinds. Birch is also a good wood for fuel and distillation.

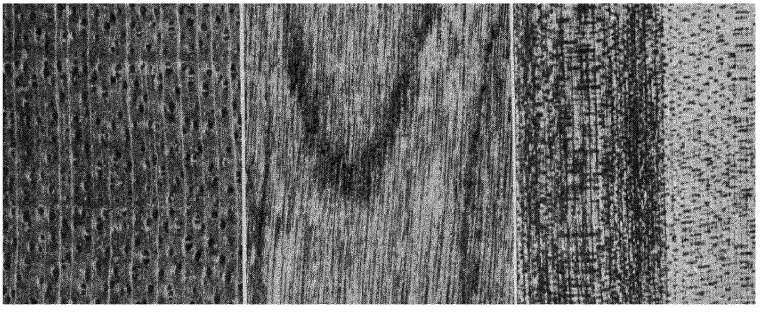
Cherry

The wild black cherry (*Prunus serotina*) is the only one of the several species of the genus which has a wood of commercial importance. This tree occurs in the deciduous forest area from Ontario to Florida and from the Dakotas to Texas. It is especially abundant in the southern Appalachians. The wood is hard, with a fine, straight, close grain. It varies in color from a light to a dark red depending on the age, and is often stained before use. Because of its beautiful grain and color and the ease with which it can be worked, cherry is especially desirable for furniture and interior finish and cabinetwork. At the present time it is but little used, as the supply has greatly diminished. Minor uses include the bases of scientific instruments, printer's supplies, pattern making, and turnery.



Cross-section Tangential section Radial section

BEECH



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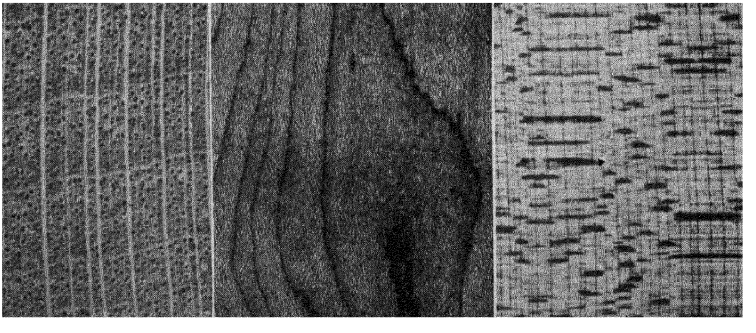
BIRCH



Cross-section Tangential section Radial section

SUGAR MAPLE

FIG. 45.—Cross, tangential, and radial sections of the wood of the beech (*Fagus grandifolia*), birch (*Betula* sp.), and sugar maple (*Acer saccharum*). (*Reproduced from Holtman, Wood Construction, McGraw-Hill Book Company, Inc.*)

Chestnut

Until its almost complete destruction by the chestnut-blight disease, the chestnut (*Castanea dentata*) was one of the most important timber trees of the eastern United States. At one time it was a conspicuous member, in both size and abundance, of the deciduous forests from Maine to Tennessee, attaining its best development in the southern Appalachians. The soft, light,



FIG. 46.—A typical American or white elm (*Ulmus americana*), showing its characteristic graceful habit. (*Reproduced by permission from Foster, Elementary Woodworking, Ginn and Company.*)

open-grained wood is very durable and easy to work. Chestnut is used for millwork, furniture, caskets, musical instruments, boxes, woodenware, and veneers. Because of its durability it is an excellent wood for posts, poles, piling, ties, fence rails, cooperage, and shingles. It is also a source of pulpwood and a tanning material.

Elm

Several species of elm, especially the rock elm (*Ulmus racemosa*) and the white elm (*U. americana*), yield a valuable wood with a

beautiful grain. The wood of the rock elm is tough, strong, hard, heavy, elastic, and durable. Next to hickory it is the most important source of hubs, spokes, fellies, and rims of wheels. It is also used for agricultural implements and tool handles, butcher blocks, veneers, and cooperage, and in the manufacture of furniture, refrigerators, musical instruments, and woodenware. The white elm (Fig. 46) has a lighter, softer, and weaker wood, which, however, is tough and fibrous and is used for much the same purposes.

Hickory

The hickories are found in the eastern deciduous forest area from Ontario to Minnesota, Florida, and Mexico. Although the wood of all the species is used to some extent, the most important sources are the shagbark hickory (*Carya ovata*), the mockernut (*C. alba*), and the pignut (*C. glabra*). Hickory is one of the toughest, hardest, heaviest, and strongest of woods and is used where both strength and the ability to withstand shocks are required. It is a coarse straight-grained wood. The sapwood is preferable to the heartwood. Hickory is used chiefly for spokes, fellies, axles, and other parts of wagons; also for ax, pick, and hammer handles; baseball bats; agricultural implements; shafts of golf clubs; pump rods; and cooperage.

Locust

The black locust (*Robinia pseudoacacia*), another tree of the eastern deciduous forest region, also yields an exceedingly heavy strong, hard, durable, and elastic wood. Locust has a coarse, open, crooked, compact grain and a smooth, satiny surface. Its chief use is for insulator pins and brackets. Other uses include tree nails, boat ribs, fence posts, ties, sills, wagon hubs, and mine timbers. The wood is of more importance in England, where it is used for furniture and shipbuilding. The honey locust (*Gleditsia triacanthos*), with similar properties and uses, is of minor importance.

Maple

Maple is one of the more important woods. The chief source of commercial wood is the rock or sugar maple (*Acer saccharum*). This tree, a conspicuous species of the eastern deciduous and

northeastern transition forests, ranges from southeastern Canada to Georgia. Two other eastern species, the silver maple (*A. saccharinum*) and the red maple (*A. rubrum*), and the Oregon maple (*A. macrophyllum*), found in Washington and Oregon, are also used. Maple wood is heavy, tough, compact, strong, and very hard. It is light brown in color with a dense even grain and fine texture (Fig. 45). It is susceptible of a fine polish, and is often beautifully grained and figured, as in the case of curly and bird's-eye maple. These latter characteristics make it one of the best woods for furniture, veneers, flooring, and interior finish. It is also used for violins, shoe lasts, rulers, tool handles, inlays, panels, keels of vessels, pianos, violins and other musical instruments, bowls, cooperage, charcoal, fuel, and wood-distillation products. The sap of the maple furnishes us with maple sirup and maple sugar.

Oak

Oak is the most important of the hardwoods and stands in fourth place among all the woods. Not only is the timber important, but the oaks are the largest and finest of the hardwood trees of the forest. Oak wood is hard, tough, durable, resilient, and elastic. Its great strength and ability to resist heavy strains render it valuable for shipbuilding and all types of heavy construction. It is also capable of a high polish and is unrivaled for decorative work, especially in the form of quartered oak. Over fifty species of oak occur in the United States, some twenty of which are of commercial importance. These belong either to the white oak, or to the red oak group. It is difficult to distinguish between the wood of the individual species and they are known in the trade as either white, or red, oak.

White oak lumber is harder, stronger, and more durable. It is used for bridge and building timbers, piling, ties, parts of machinery, agricultural implements, furniture, flooring, cabinetwork, interior finish, and cooperage. In the latter connection it is of interest to note that oak barrels are the only satisfactory containers for beer, wine, and alcoholic spirits. The most important species in this group include the white oak (*Quercus alba*) (Fig. 47), the bur oak (*Q. macrocarpa*), the over-cup oak (*Q. lyrata*), the post oak (*Q. stellata*), the chestnut oak (*Q. mon-*

tana), the swamp chestnut oak (*Q. Prinus*), the Oregon oak (*Q. Garryana*), and the swamp white oak (*Q. bicolor*).

Red oak lumber is softer, more porous, more open-grained, and less durable. It has practically the same uses, but is less highly esteemed. The principal species include the red oak (*Quercus*

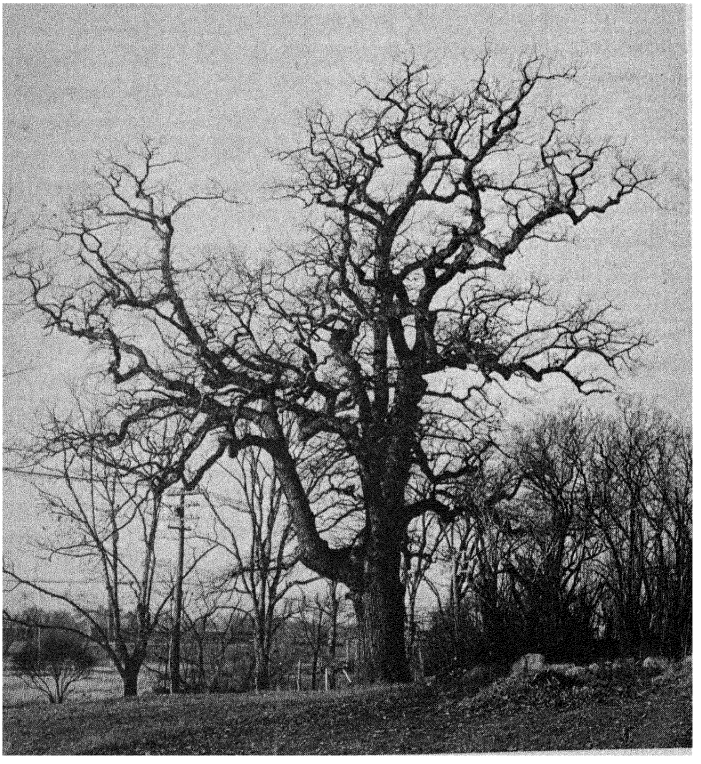


FIG. 47.—A famous white oak (*Quercus alba*), the Avery oak in Dedham, Mass. It is estimated that this tree was full grown in 1636. (*Photo by E. H. Wilson; courtesy of the Arnold Arboretum.*)

borealis), the black oak (*Q. velutina*), the scarlet oak (*Q. coccinea*), the pin oak (*Q. palustris*), the turkey oak (*Q. Catesbaei*), the willow oak (*Q. phellos*), the Texas red oak (*Q. texana*), and the shingle oak (*Q. imbricaria*).

The **live oak** (*Quercus virginiana*), a quite distinct, evergreen species, has the hardest, strongest, and toughest wood of all the oaks. It is used in the construction of wagons, ships, and farm tools. Only a comparatively small amount is available.

Osage Orange

The osage orange (*Maclura pomifera*) is a small tree, native to the Gulf States, but cultivated elsewhere Its wood is the heaviest, toughest, and hardest of all the native hardwoods. Only a little is available and this is used chiefly for felloes, insulator pins, tree nails, and woodenware. The Indians used this wood for bows. It is also the source of a dyestuff. Because of its durability it is used for fence posts.

Poplar

The true poplars of the United States are known commercially under several different names. The most important tree is the cottonwood (*Populus balsamifera*) of the Central and Eastern states. It has a soft, light, even-grained, fibrous wood, which is easily worked. Its chief uses are as a substitute for basswood in the manufacture of boxes and excelsior, and as a pulpwood It is also used for millwork, woodenware, and plywood The balsam poplar (*P. Tacamahacca*), several other large poplars, and the much smaller aspens (*P. tremuloides* and *P. grandidentata*) have similar uses. Aspen wood is also used in furniture, in cooperage, and for matches and pulp.

Red Gum

The red gum or sweet gum (*Liquidambar Styraciflua*) (Fig. 48) has greatly increased in importance as a commercial wood during the past few decades. The tree ranges from Connecticut to the mountains of Central America, attaining its best development in the Southeastern states. The wood is light and soft, but tough and resilient. It is reddish brown in color, with a fine, straight, close grain, and it polishes well Red gum is often stained to imitate cherry, walnut, or mahogany. It is used for furniture, cabinetwork, interior finish, fancy boxes, veneers, and cooperage. Red gum wood is extensively used in England under the name of satin walnut. The tree is the source of storax, a medicinal product.

Sycamore

The sycamore (*Platanus occidentalis*), with its characteristic bark which peels off in large patches, is a familiar tree throughout

the eastern deciduous forest region. The wood is hard, tough, strong, and very durable. It is light reddish brown in color with a close uneven grain. When quartersawed, a mottled figure with lustrous rays is obtained. This is often marketed as *lacewood*. Sycamore is extensively used for tobacco boxes and other containers as it does not impart any odor. It is also used for

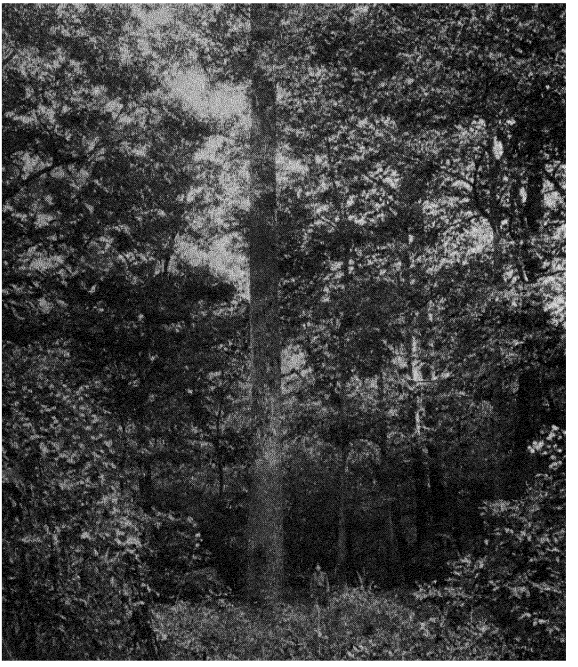


FIG. 48.—A large sweet gum (*Liquidambar Styraciflua*) in the De Soto National Forest, Mississippi. (*Photo by U.S. Forest Service.*)

furniture, millwork, interior decoration, butcher blocks, yokes, cooperage, brushes, and plywood.

Tulip

The tulip tree (*Liriodendron Tulipifera*) is one of the largest trees (Fig. 49) of the eastern deciduous forest, reaching a height of from 125 to 250 ft. and a diameter of 6 to 14 ft. The wood, which is known commercially as yellow poplar or whitewood, is of great importance. It is soft, light, and easily worked, with

a fine straight grain. It is also stiff and durable, although not very strong. It is used for millwork, boxes, furniture, carriage bodies, musical instruments, woodenware, toys, boats, light construction, and veneers.

Tupelo

Two species are known commercially as tupelo, black gum, or sour gum. *Nyssa sylvatica* is found from Maine to Michigan and south to Florida and Texas, while *N. aquatica* is restricted to the swamps of the Southern states. The wood is pale yellow with a dense, fine, twisted, and interwoven grain. It is soft, light, tough, stiff, and resistant to wear. Tupelo has increased in importance in recent years. It is used for flooring, tobacco boxes, wheel hubs, woodenware, veneers, ties, handles, yokes, pulp, rollers, and piling.

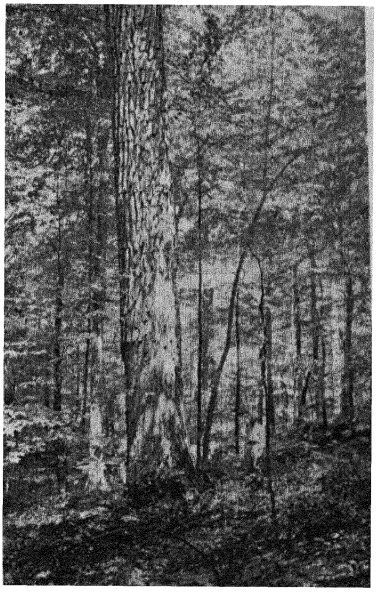


FIG. 49.—An old-growth tulip poplar (*Liriodendron Tulipifera*) in Virginia. (*Photo by U.S. Forest Service.*)

Walnut and Butternut

The black walnut (*Juglans nigra*) has always been one of the most valuable native woods. It is a large tree (Fig. 50) of the deciduous forest region, ranging from Massachusetts to Florida and from Minnesota to Texas. The wood is moderately hard, tough, and strong and is easily worked. It is very durable. The color varies from a rich dark brown to a purplish black. The wood has a fine even grain and a good figure and is capable of taking a high polish. Black walnut has been extensively exploited and consequently is scarce; it is so high priced that it is even sold by the pound. Since the seventeenth century it has been the chief wood used for gun stocks. Other important uses include furniture, cabinetwork, millwork, musical instru-

ments, airplane propellers, sewing machines, and veneers. Before it became so valuable the wood was used locally for fences, barns, and light construction.

The butternut (*Juglans cinerea*), which extends from New Brunswick to Minnesota and south to Georgia and Arkansas,

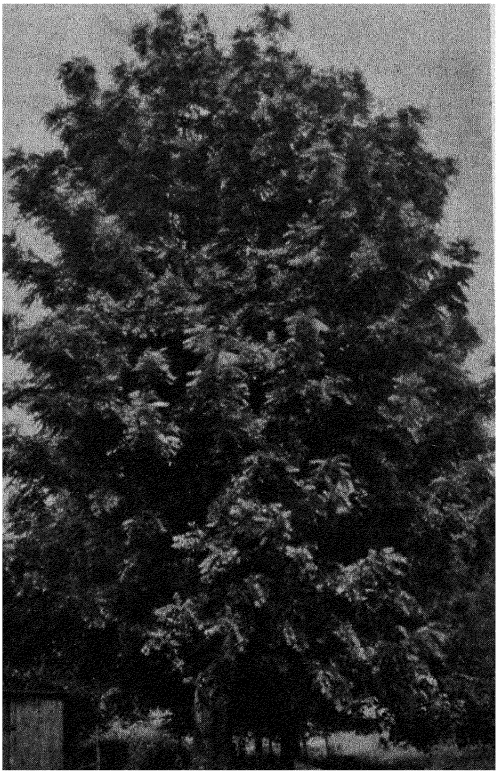


FIG. 50.—A black walnut (*Juglans nigra*) in North Carolina. (*Photo by U.S. Forest Service.*)

has a wood of somewhat similar nature and uses. The figure is like that of black walnut, so it makes a good substitute for the former. The wood, however, lacks the color and is not so strong. It is used chiefly for furniture, boxes and crates, excelsior, millwork, and woodenware. Sugar is sometimes obtained from the sap of the butternut and a dye from the green husks that surround the fruit.

Minor Species

While all the other woody plants serve some useful purpose in industry, or are valuable, at least for fuel, it will be possible to mention only a few of them.

Apple (*Pyrus Malus*).—Apple wood, usually obtained from old orchards, is very strong, hard, and compact, with a uniform close grain. It is used principally for tool handles, pipes, knobs, mallet heads, rulers, canes, and turnery.

Red Alder (*Alnus rubra*).—This, the largest of the alders, occurs in Oregon and Washington west of the Cascade Range. The wood, which has a fine even grain, uniform texture, and a reddish-brown color, works and polishes well and gives a good imitation of mahogany and black walnut. The factories in the states where the tree is native use red alder more than all other woods combined, chiefly for furniture, millwork, handles, and novelties.

Blue Beech (*Carpinus caroliniana*) —This small tree of eastern North America has a heavy, strong, and very stiff wood. No other wood has been found which is as suitable for levers. It is also used for tool handles.

Buckeye (*Aesculus octandra*).—This tree of the Middle West furnishes a soft light wood used for boxes, excelsior, millwork, furniture, trunks, and artificial limbs.

Cucumber (*Magnolia acuminata*).—This tree, the largest and most abundant of the magnolias, is particularly characteristic of the southern portion of the deciduous forest area. Its soft, light, durable wood is used for millwork, woodenware, boxes, excelsior, and cheap furniture. It is often sold as yellow poplar

Dogwood (*Cornus florida*).—This small tree, found throughout the eastern United States, reaches its best development in the South. The wood is very hard and heavy, with a fine, lustrous, close grain. Dogwood is used primarily for shuttles for cotton mills, as it is very resistant to wear. Other uses include mauls, wedges, bobbins, golf-club heads, engraver's blocks, and cogs. Only the sapwood is used.

Catalpa (*Catalpa speciosa*).—This small tree, a native of the lower Ohio valley, is extensively planted throughout the Middle West. The wood is very durable and is much used for ties and fence posts.

Coffee Tree (*Gymnocladus dioica*).—This species of the eastern deciduous forest has a strong and durable wood used for furniture, interior finish, sills, bridges, posts, ties, and fuel.

Hackberry (*Celtis occidentalis*).—This eastern tree has a tough, strong, heavy, and moderately hard wood, used chiefly in millwork and for boxes, woodenware, vehicles, furniture, and cooperage.

Holly (*Ilex opaca*).—This characteristic tree of the Southern coastal states and the lower Mississippi and Ohio valleys is best known by its leaves and fruit, which are almost universally used for Christmas decorations. The tough, close-grained, whitish wood is used for inlays, brushes, woodenware, and fancy articles, and is often stained to imitate ebony.

Hornbeam (*Ostrya virginiana*).—The wood of the hornbeam, which occurs in eastern North America, is one of the hardest, toughest, and strongest known, but is available only in small amounts. It is used for handles, carriage parts, levers, and fence posts.

Persimmon (*Diospyros virginiana*).—The sapwood of this southeastern species is very heavy, tough, hard, strong, elastic, and resistant to wear. It is used chiefly for shuttles, and also for boot and shoe findings, for golf-club heads and other sporting goods, and in turnery.

Sassafras (*Sassafras albidum*).—This small tree of the eastern United States is especially abundant in the Southern and Gulf States. Small amounts of the fragrant, durable, soft, and light wood are available. It is used for millwork, furniture, cooperage, fence rails and posts, and boxes.

Willow (*Salix nigra*).—This is the only one of the numerous willows which is of commercial importance. It reaches its best development on the flood plains in the Mississippi and Ohio valleys. The smooth wood is soft, light, tough, and fairly strong. It is used for boxes and crates, excelsior, bats, boats, water wheels, and charcoal. The long, slender, pliable young shoots are used for wicker baskets and furniture.

FORESTS OF SOUTH AMERICA

The forests of South America cover 44 per cent of the land area. They consist principally of tropical hardwoods (89.3 per cent), with some temperate hardwoods (5.5 per cent) and conifers

(5.2 per cent). Two types of tropical hardwoods occur. The most abundant is the dense humid rain forest which characterizes the Guianas and the great Amazon and Orinoco River basins and which also occurs along the eastern coast of Brazil. This forest is noteworthy for the great number of species and for the size and frequency of the individual trees. It is estimated that there are over 2500 different tree species in the Amazon forest alone. This forest, which is often said to be the most extensive body of solid forest in the world, has but little vegetation on the forest floor, owing to the density of the canopy. Epiphytes and lianas, however, are frequent and characteristic. In drier parts of Brazil and Argentina an open deciduous type of tropical forest occurs. Mixed forests of conifers and temperate hardwoods occur along the northern Andes, and again in the southern Cordilleras. Conifer forests, consisting chiefly of Paraná pine (*Araucaria angustifolia*) cover large areas in southern Brazil and Argentina, while similar areas, with *Araucaria araucana* the dominant species, occur in Chili. In Paraguay and Argentina there are extensive areas of open forests composed chiefly of quebracho (*Schinopsis Lorentzii*), the most important source of tanwood.

Important Woods of Tropical America

The tropical forests of Mexico, Central America, the West Indies, and South America have long been utilized as the source of most of the high-grade cabinet and furniture woods of commerce, and to some extent for timber for general construction. However, these forests have been but little exploited as a source of ordinary lumber up to the present time, and they constitute a vast reservoir for future needs. The number of available species is enormous. Brazil alone is said to have over 3000 woody species, including some 50 of the most valuable cabinet woods. Because of their importance in the United States, a few of these tropical woods will be discussed.

Balsa (*Ochroma pyramidale*).—This wood, which is found in Central America, the West Indies, and Northern South America, is the lightest known commercial wood (Fig. 51). It is very soft and pithy, and is used as a substitute for cork in life rafts and floats and for insulating purposes.

Boxwood.—The West Indian boxwood or zapatero (*Casearia praecox*) is much used as a substitute for the European boxwood in the manufacture of engraver's blocks, rulers and other scientific instruments, shuttles, spools, bobbins, musical instruments, and veneers. The supply comes chiefly from Venezuela.

Cedar.—The Spanish or cigar-box cedar (*Cedrela odorata*) is widely distributed throughout tropical America, both as a native and as an introduced species. It has a reddish-brown aromatic heartwood with a straight coarse grain. The wood is used

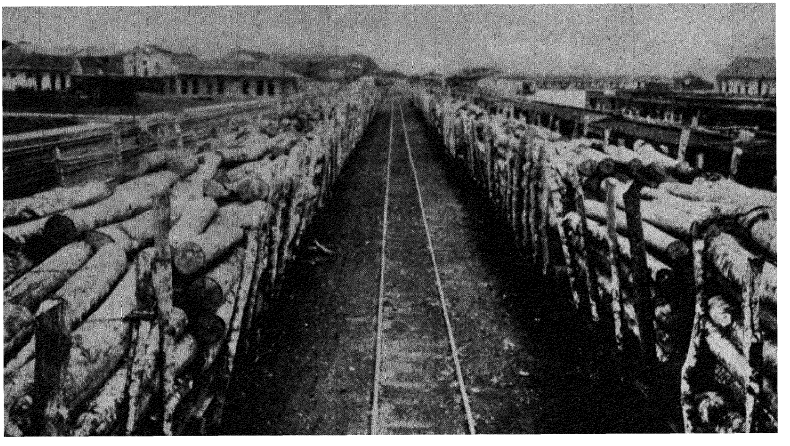


FIG. 51.—Logs of balsa wood (*Ochroma pyramidale*) awaiting shipment. (*Courtesy of S. J. Record.*)

chiefly for cigar boxes, as it is insect repellent. It is also used for closets, chests, shingles, and as a substitute for mahogany.

Cocus Wood.—This wood (*Brya Ebenus*), also known as American ebony or granadillo, is used for knife handles, musical instruments, principally flutes and clarinets, turnery, inlays, and cabinetwork. The wood is very hard and durable and polishes well. It comes from Mexico, the West Indies, Central America, and Venezuela.

Cocobolo.—Cocobolo, obtained from *Dalbergia retusa*, a tree found from Mexico to Panama, is one of the showiest and most strikingly colored of the exotic woods. The heartwood is orange to orange-red in color, streaked with jet black. The wood is very hard, tough, and strong. It is used for instruments, knife and umbrella handles, inlays, lacquer, and turnery.

Crabwood.—The crabwood (*Carapa guianensis*) attains its best development in the Guianas, although it occurs in other parts of South America and in the West Indies. The very strong and hard rich-brown wood is used as a substitute for mahogany.

Greenheart.—The greenheart (*Nectandra Rodioei*), a native of British Guiana (Fig. 52), furnishes structural timbers of great value. The wood is one of the strongest, and is very hard, heavy, tough, and elastic; it is much used, particularly in Europe, for bridges, piles, wharves, and shipbuilding. Other uses include shafts, spokes, and fishing rods. The wood receives its name from its peculiar greenish-brown color.



FIG. 52.—Felling a greenheart tree (*Nectandra Rodioei*) in British Guiana. (*Photo by C. D. Mell; courtesy of S. J. Record.*)

Lancewood.—Two West Indian species, the lancewood (*Oxandra lanceolata*) and the degame (*Calycophyllum candidissimum*), furnish the lancewood of commerce. This wood is yellowish, with a fine close grain, and is very tough, strong, and elastic. It is used for fish poles, spars, shafts, ramrods, whips, cues, bows, lances, and turnery.

Letterwood.—The letterwood or snakewood (*Piratinera guianensis*) of British Guiana yields a very ornamental wood. It is brown in color with peculiar black markings (Fig. 27) and a close, fine, lustrous grain. It is used for canes, umbrellas, drumsticks, violin bows, veneers, and inlays.

Lignum Vitae.—This important wood (Fig. 53) is obtained chiefly from two species, *Guaiacum officinale* and *G. sanctum*, found in southern Mexico, Central America, and the West Indies. Lignum vitae is the hardest of the commercial woods, and is naturally very tough and strong. It is dark brown, streaked with black, and has a very fine, intricately woven grain.

It has many uses, including bowling balls and other sporting goods, pulley blocks and conveyors, bearings and bushings, instruments, and furniture. Lignum vitae also yields the gum resin, guiacum, used in medicine.

Locust.—The West Indian locust (*Hymenaea Courbaril*) is one of the most important timber trees of tropical America. The hard tough wood is used for general carpentry work, furniture, shipbuilding, and cabinetwork. This tree is the source of South American copal.



FIG. 53.—Shipping logs of lignum vitae (*Guaiacum officinale*) in Haiti. (*Photo by C. D. Mell; courtesy of S. J. Record.*)

Mahogany.—Mahogany is the most important of the woods imported into the United States, and is the premier cabinet wood of the world. Its use as a furniture wood dates back to 1700, when it was introduced into England by the famous Chippendale. The true mahogany (*Swietenia Mahogani*), or Spanish mahogany as it is usually called, grows from the Florida Keys to Central America and in the West Indies. It has also been introduced into other tropical countries. The tree (Fig. 54) is an ornamental evergreen species and reaches a height of from 40 to 50 ft., with large buttresses at the base. The wood is reddish brown in color with a crooked grain. It is very strong, hard, and heavy, and polishes and glues well. It is used for furniture and fixtures, musical instruments, millwork, cars, ships and boats, caskets and coffins, and veneers. Mahogany has many imitations and

substitutes. In addition to the species mentioned elsewhere may be added Colombian mahogany (*Cariniana pyriformis*).

Majagua.—The majagua or blue mahoe (*Hibiscus elatus*) of the West Indies has already been referred to as the source of Cuba bast. The hard and slightly aromatic wood has a lustrous

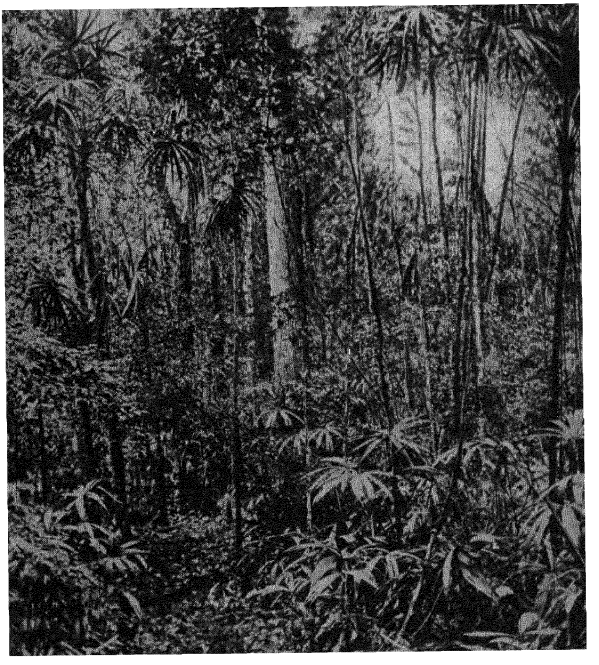


FIG. 54.—A large mahogany tree (*Swietenia Mahogani*) in a tropical jungle in British Honduras. (*Photo by U.S. Forest Service.*)

open grain. It is used for cabinetwork, carriages, gun stocks, fishing rods, and ship's knees.

Mora.—The mora (*Dimorphandra Mora*) of British Guiana and Trinidad yields a brown wood, which is very hard, tough, and even more durable than teak. It has been used chiefly in Europe for shipbuilding, platforms, ties, and all types of heavy construction.

Prima Vera.—This cream-colored wood, sometimes called white mahogany, is obtained from *Tabebuia Donnell-Smithii* of southern Mexico and Guatemala. It is used for furniture and fixtures, millwork, ships, boats, cars, and veneers.

Purpleheart.—*Peltogyne paniculata*, the purpleheart of the Guianas and Trinidad, has a very hard, tough, strong, durable brown wood, which turns a purple color on exposure. It is used for heavy construction, furniture, billiard tables, cues, fishing rods, inlays, and turnery.

Rosewood.—Of several different rosewoods, the Brazilian rosewood (*Dalbergia nigra*) is the best. The dark purple, almost black, wood is often striped and has a coarse, dense, even grain. Rosewood is one of the finest cabinet woods and is also used for scientific instruments, furniture, pianos, cars, sporting and athletic goods, handles, and brushes.

Satinwood.—The West Indian satinwood (*Zanthoxylum flavum*) has long been a favorite furniture wood. It was especially esteemed in England by such builders as Sheraton, Adam, and Heppelwhite. The wood is smooth and lustrous and slightly oily. It has a very close, dense, even grain. Other uses include millwork, musical instruments, caskets, brushes, cabinetwork, and veneers.

FORESTS OF EUROPE

In Europe forests occupy about 31.3 per cent of the land area. Seventy-four per cent of these forests are classed as coniferous, 24 per cent as temperate hardwoods, and 1.6 per cent as mixed forests. The coniferous woodlands are especially characteristic of the northern portion of the continent, while the hardwood and mixed forests are found in Southern and Western Europe. The original forest cover of Europe has been severely depleted as the result of long utilization and the necessity of clearing the land for agriculture and other purposes. In Great Britain only 5 per cent of the original forest is left, and in France, Spain, Belgium, Italy, and Greece from 10 to 20 per cent. Sweden and Finland still have over half their forests available and, together with Russia, are the most heavily forested regions in Europe.

The most striking feature of the European forests to an American is the presence of the same genera that are found in the New World, although these are usually represented by different species. The principal conifers are the Scotch pine (*Pinus sylvestris*) and Norway spruce (*Picea Abies*), which furnish the woods known as yellow deal and white deal respectively. Other

conifers include the cluster pine (*Pinus Pinaster*), the Corsican pine (*Pinus Laricio*), the stone pine (*Pinus Pinea*), the silver fir (*Abies alba*), larch (*Larix decidua*), and yew (*Taxus baccata*). The American white pine and Douglas fir are extensively planted.

The most important hardwoods are the oaks, chief among which are *Quercus Cerris, Q. conferta, Q. Robur,* and *Q. sessilifolia.* Other prominent hardwoods include the black alder (*Alnus glutinosa*), ash (*Fraxinus excelsior*), beech (*Fagus sylvatica*), birches (*Betula pendula* and *B. pubescens*), cherry (*Prunus Cerasus*), chestnut (*Castanea sativa*), elm (*Ulmus procera*), hazel (*Corylus Avellana*), holly (*Ilex Aquifolium*), hornbeam (*Carpinus Betulus*), lime (*Tilia cordata*), maple (*Acer pseudoplatanus*), plane (*Platanus orientalis*), rowan (*Sorbus Aucuparia*), blackthorn or sloe (*Prunus spinosa*), and willow (*Salix alba*).

A few European species are imported into the United States. These include the boxwood, walnut, briar, and olive.

The so-called Turkish boxwood (*Buxus sempervirens*), of Southern Europe, Asia Minor, and Northern Africa, has been used for so many centuries that the supply has almost disappeared. The wood is very hard, with a fine, dense, uniform grain, and a smooth, somewhat lustrous texture. It is used for blocks for wood engraving, rulers and other instruments, shuttles, bobbins, firearms, whips, canes, umbrellas, inlays, and turnery.

The English walnut (*Juglans regia*), known commercially as the Circassian walnut, occurs from the Black Sea region across Asia Minor and Persia to northern India. Its hard wood is beautifully figured and takes a high polish. Material obtained from burls is especially desirable. It is used for furniture and fixtures, millwork, musical instruments, firearms, cabinetwork, turnery, and veneers.

Olive wood from *Olea europaea* is imported for brushes, canes, and turnery; and briar root (*Erica arborea*) for tobacco pipes

FORESTS OF ASIA

In Asia forests cover 21.6 per cent of the land area. They are especially abundant in the northern and eastern parts of the continent and very sparse in the southwest. As in other localities, much of the original forest area has been destroyed. This is especially true of China, where centuries of cultivation have not

only destroyed the forests, but much of the arable land as well, as a result of too extensive cultivation and subsequent erosion.

Conifers comprise 42.4 per cent of the forest area. They are characteristic of most of Siberia and also occur in the Himalayas and the mountains of Asia Minor, China, and Japan. Temperate hardwoods make up 27.3 per cent of the forests. These hardwoods, and mixed forests as well, are found in the southern provinces of Soviet Russia, Afghanistan, Persia, Asia Minor, China, and Japan. In the case of both the conifers and the temperate hardwoods, European species are found in the western part of the continent, giving way to more distinctive Asiatic species of the same genera in the east. Pine, spruce, fir, juniper, cedar, maple, ash, basswood, poplar, alder, birch, walnut, oak, larch, and yew are all represented. The United States imports some oak from Siberia, and maple from Japan.

Tropical hardwoods make up 30.3 per cent of the total forest area, and are found south of the Himalayas. In many countries they comprise 100 per cent of the woody species. This is true of Ceylon, Siam, the East Indies, and Malaya. As in other tropical forests elsewhere, the number of species is very great. India is estimated to have 2000 and Japan 1000 different species. Many of these Asiatic forests are dominated by teak, while others are composed chiefly of members of the *Dipterocarpaceae* and *Leguminosae*. Seventy-five per cent of the Philippine forest trees belong to the former family. A considerable number of these Asiatic woods enter into foreign trade, and a few are imported into the United States. These include ebony, padouk, satinwood, and teak.

Ebony.—Several species furnish a wood known as ebony, the most important of which is the Macassar ebony (*Diospyros Ebenum*), which is found from India and Ceylon to the East Indies. Ebony is a black wood with brown stripes. It is very hard and heavy, and has a fine grain. It takes a high polish and has long been a famous cabinet wood. Other uses include whips, canes, umbrellas, piano keys, sporting and athletic goods, handles, inlays, and turnery.

Padouk.—This wood, obtained from *Pterocarpus indicus*, is very ornamental. It is red in color with black stripes and is very lustrous. It is hard and durable and polishes well. Padouk is used for furniture, fine cabinetwork, millwork, car construction, turnery, and veneers.

Satinwood.—The East Indian satinwood (*Chloroxylon Swietenia*) has an extremely hard yellowish or dark-brown heartwood, which is sometimes mottled. It has a satiny luster and a fine, dense, even grain. Satinwood is used for furniture, cabinetwork, veneers, and brushes.

Teak.—Teak (*Tectona grandis*) (Fig. 55) is one of the most durable of woods and one of the most important commercial timbers of the tropics. It is hard and does not warp, split, or



FIG. 55.—Logs of teak (*Tectona grandis*) in Burma. Elephants are often used in the lumbering operations. (*Photo by U.S. Forest Service.*)

crack, and so makes a valuable timber for general construction. The wood is yellowish brown in color and greasy to the touch. It is extensively used in ship and boat building, and for furniture, millwork, piles, railway cars, flooring, and greenhouses.

Other important woods of tropical Asia include the acle or pyinkado (*Xylia xylocarpa*), sal (*Shorea robusta*), and sissoo (*Dalbergia Sissoo*), all used for general construction, and the following cabinet woods: Moulmein cedar (*Cedrela Toona*), laurelwood (*Calophyllum inophyllum*), rosewood (*Dalbergia latifolia*), and sandalwood (*Santalum album*).

FORESTS OF AFRICA

In Africa forests cover only 10.7 per cent of the land area. Tropical hardwoods predominate, comprising 96.9 per cent of the forests, with temperate hardwoods accounting for 2.2 per cent,

and conifers only 0.9 per cent. Conifers are restricted to the Mediterranean region, the high mountains of Central and Eastern Africa, and South Africa. Two types of tropical forest occur. The most extensive is the dense rain forest which covers much of equatorial Africa, particularly the West African coast and the Congo basin. This region has a uniformly distributed rainfall amounting to 60 to 160 in. Important elements of this forest are the mangrove swamps along the coast. An open parklike forest occurs in regions where the rainfall amounts to 30 to 40 in. Large areas of this type of forest occur in the northeastern and southern parts of Africa, particularly in Angola and Rhodesia. There are many important woods that resemble the better known woods of tropical America and Asia, but they have been but little exploited as yet. The United States imports only one wood, the African mahogany (*Khaya senegalensis*), a West Coast species. This is a beautifully figured and richly colored wood, which is much used as a substitute for true mahogany.

FORESTS OF AUSTRALIA AND OCEANIA

Forests cover only 5.8 per cent of the land area in Australia, while in New Zealand 25.7 per cent of the land is forested, and in Oceania 71 per cent. The most heavily forested regions are New Guinea with 80 per cent, Samoa with 70 per cent, and Tasmania with 64.7 per cent. In Australia 4 per cent of the forests are coniferous, 11 per cent are temperate hardwoods, and the remainder are tropical hardwoods. Conifers occur in New South Wales, Queensland, and Tasmania, and temperate hardwoods only in Tasmania. Tropical hardwoods occur in all the states except Tasmania. These forests rival those of Pacific North America in size and density. The species are different from those found in other parts of the world. Most of them are either eucalypts or acacias. There are over 70 commercial species of *Eucalyptus*, the most important of which are the karri (*E. diversicolor*) and jarrah (*E. marginata*) of Western Australia. The former reaches a height of 300 ft., with a clear length of 180 ft. Other valuable trees are the blackwood (*Acacia melanoxylon*) and silky oak (*Grevillea robusta*). The principal coniferous species is *Araucaria Cunninghamii*.

In New Zealand 68 per cent of the forests are coniferous and the remainder temperate hardwoods. The chief species is the

huge kauri pine (*Agathis australis*), one of the largest timber-producing trees in the world. The wood is strong and durable and very free from knots. It is exported in large quantities. Kauri is also the source of an important resin. Other valuable species include the white pine (*Podocarpus dacrydioides*), totara (*Podocarpus Totara*), red pine (*Dacrydium cupressinum*), and several beeches.

The forests of Oceania are entirely composed of tropical hardwoods, and none of them are of importance, except locally

CHAPTER V

TANNING AND DYE MATERIALS

TANNINS

Tannins are organic compounds, chiefly glucosidal in nature, which have an acid reaction and are very astringent. Their biological function is problematical. They may be concerned with the formation of cork or pigments, or with the protection of the plant. Tannins are of interest economically because of their ability to unite with certain types of proteins, such as those in animal skins, to form a strong, flexible, resistant, insoluble substance known as leather. Because of this property of "tanning" hides, tannin-containing materials are in great demand. Tannins also react with salts of iron to form dark-blue or greenish-black compounds, the basis of our common inks. Because of their astringent nature they are useful in medicine.

Although nearly all plants contain some tannin, only a few species have a sufficient amount to be of commercial importance. Tannins are found in the cell sap (Fig. 3) or in other definite areas in bark, wood, leaves, roots, fruits, and galls. In most cases these structures are of little value otherwise, so the extraction of tannin is usually incidental to other industries.

The Tanning Industry

Tanning is a very old industry. The Chinese tanned leather over 3000 years ago. The Romans used oak bark for tanning skins. In more recent times the American Indians utilized several native plants in curing their buffalo hides. The first tannery in the United States was established in Virginia in 1630. Twenty years later there were over 50 in New England alone. The industry developed in this region because it was here that the chief raw material, hemlock bark, was most abundant and cheapest. By 1816 the business was worth over $200,000,000, and Boston had become one of the chief leather markets of the world. Fifty years later the industry began to shift westward

and southward, as the hemlock became scarce, and many tanneries were established in Pennsylvania. Here oak was used extensively. Still later other tanneries sprang up in the Southern states, using chestnut as a raw material. As the native species became scarce, other sources began to be utilized, including western trees, and foreign products as well The development in recent years of concentrated extracts with a high tannin content has greatly increased the number of available sources. At first each company made its own supply, but now extracts can be imported, and many foreign species have been developed as raw materials of first importance. The world's supply of tanning materials is very abundant and much of it is as yet untouched. The United States supplies only a small part, chiefly hemlock, oak, chestnut, sumac, and canaigre

Sources of Tanning Materials

Nearly all the sources of tannin occur in the wild state, very few being cultivated The more important raw materials will be discussed according to their morphological origin

Barks

Hemlock.—From the earliest time the hemlock (*Tsuga canadensis*) has been the chief domestic source of tannin in the United States. Its continued utilization for this purpose has contributed greatly to the gradual elimination of this species as an important member of our forests. Wasteful methods were employed, and often the trees were felled and allowed to rot after the bark was removed. Hemlock bark (Fig. 56) contains 8 to 14 per cent tannin It is used for sheepskins and for sole and other heavy leathers, either alone or in combination with oak. Extracts are now available with a tannin content as high as 28 to 30 per cent. In recent years attention has been directed to the western hemlock (*T. heterophylla*), which seems destined to be one of the chief native sources of the future.

Oak.—Oak bark has been used extensively as a source of tannin, and several species are available. The most important American species is the chestnut oak (*Quercus montana*). This tree is very abundant in the Appalachian region and many tanneries have been established there. The tannin content is 6 to 11 per cent. The extract, with a 26 to 30 per cent content,

is widely used for heavy leathers. The black oak (*Q. velutina*), with about the same amount of tannin, yields the extract quercitron. This is much used although it dyes the leather a curious yellow. The California tanbark oak (*Lithocarpus densiflora*) has been utilized since 1850. This species has a yield of tannin up to 29 per cent and is of increasing importance. Red oak (*Quercus borealis*) and white oak (*Q. alba*) are used somewhat, but they contain only a small amount of tannin. European species of oak are much used in England and on the Continent.

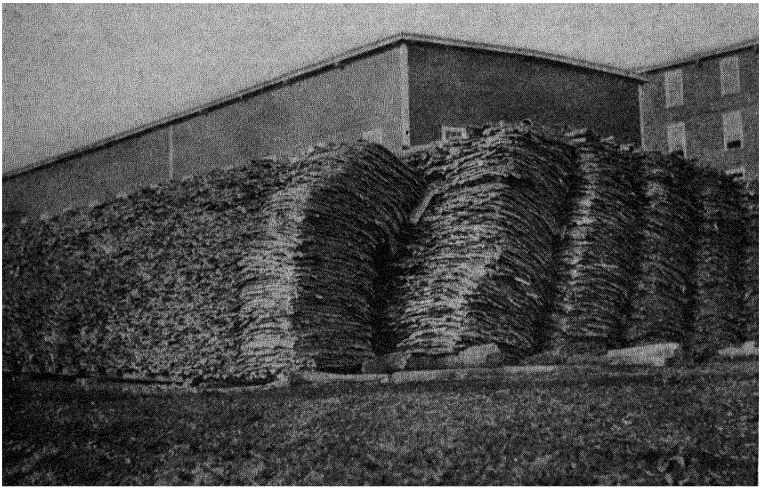


FIG. 56.—Hemlock bark ready for use, stacked at a Maine tannery. (*Photo by U.S. Forest Service.*)

Mangrove.—Mangrove bark has become very important in recent years both in this country and abroad. It gives great promise for the future as the supply is extensive and virtually untouched. Although all mangroves contain tannin, the red mangrove (*Rhizophora Mangle*) is the chief source. This tree is very abundant in the tropical swamps of both hemispheres in tidal areas (Fig. 57). The present commercial supply comes from East Africa, the East Indies, and Central America. Mangrove bark is very hard and heavy, and contains 22 to 33 per cent tannin. The leaves may also be used. The extract is the cheapest of the tanning materials. It is rarely used alone as it gives a bad color to the leather.

Wattle.—Wattle bark is an important source of tannin. It is used chiefly in Great Britain, but is of steadily increasing prominence in this country. It is the product of several species of acacias, chiefly *Acacia dealbata*, *A. decurrens*, and *A. pycnantha*. These small trees are natives of Australia, but are now cultivated extensively in South Africa, Ceylon, and elsewhere. The bark, which may have a tannin content as high as 40 to 50 per cent, is removed from the trees when they are from five to fifteen years



FIG. 57.—A mangrove (*Rhizophora Mangle*) swamp in the Solomon Islands.

of age. It is dried and ground to a powder. An extract is also available. Wattle bark yields a solid, very firm, faintly pink leather, much used for soles.

Other Barks.—Many other barks have been used as a source of tannin, but the content is too low for them to be of much commercial value. In Europe the larch (*Larix decidua*), Norway spruce (*Picea Abies*), and several birches and willows are used. Birch bark is much favored in Russia, and the fragrance of Russia leather is due to the presence of an essential oil in the bark. Willow bark furnishes a light-colored, soft, pliable leather much used for gloves. Several tropical barks are of minor importance. Mallet bark, obtained from *Eucalyptus occidentalis*

of Western Australia, has a tannin content of 35 to 50 per cent. The demand for this bark in the past has been so great that it has led to the depletion of the supply and now only a little is available. Avaram bark, from *Cassia auriculata*, is the most important tanbark of India. The babul (*Acacia arabica*), another Indian species, has tannin-containing bark, and pods as

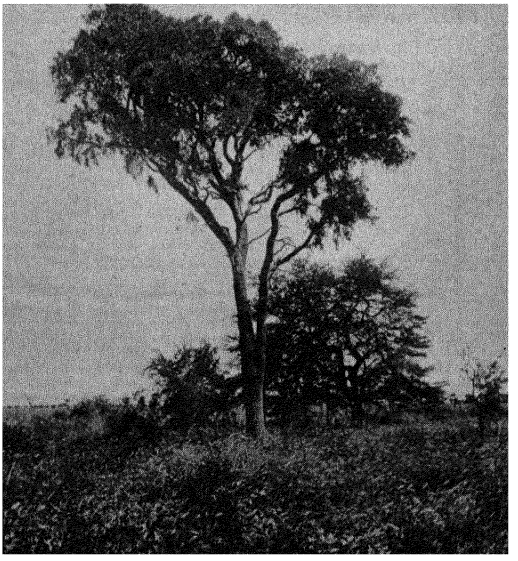


FIG. 58.—A quebracho tree (*Schinopsis Lorentzii*) in Argentina. The wood of this species is the most important source of tanning materials. (*Photo by U.S. Forest Service.*)

well, both of which are exported to Europe for making extracts. Tanekaha bark from *Phyllocladus trichomanoides*, a New Zealand tree, is used for glove leather as it contains an orange-yellow dye in addition to the tannin.

Woods

Chestnut.—The wood of the chestnut (*Castanea dentata*) was made available when the extracting process was developed. The tannin is extracted at high temperatures from chips of wood. The resulting solution is cleared, filtered, and evaporated, and eventually has a content of 30 to 40 per cent tannin. Chestnut is used for all heavy leathers. It constitutes about half of the

native tanning materials. In Europe the wood of *C. sativa* is utilized.

Quebracho.—Quebracho wood is the world's most important source of tannin at the present time. It constitutes over 85 per cent of the tanning materials imported by the United States, and 40 per cent of the amount used. Quebracho is the heartwood of a South American tree, *Schinopsis Lorentzii* (Fig. 58). The word "quebracho" means "ax breaker." The wood is one of the hardest known, with a specific gravity of 1.30 to 1.40. It was originally used for railroad ties. The first shipment of tannin was made in 1897. Argentina and Paraguay are the chief centers of the industry. Formerly the bark and sapwood were removed and then the logs were hauled out, a very laborious process. At the present time, instead of shipping the logs, extracts are made in factories located close to the source of supply. The logs are chipped and cooked with steam in copper extractors until the liquor is very concentrated, with a tannin content of 40 to 60 per cent. Quebracho is used for all kinds of leather, either alone or in combination.

Leaves

Sumac.—In the United States the dried leaves of three native sumacs, *Rhus glabra*, *R. typhina*, and *R. copallina*, are an important source of tannin. The leaves are picked in the fall when they begin to turn red, and are dried and ground into a powder. The tannin content is higher, amounting to 10 to 25 per cent, in plants growing in the Southern states.

Sicilian Sumac.—The Sicilian sumac (*Rhus coriaria*) is of even greater importance and is extensively used both in the United States and abroad. The leaves have a tannin content of 20 to 35 per cent. It yields a leather of a pale color and soft texture, the best for gloves and bookbinding. Sicilian sumac is one of the few tanning plants to be cultivated. Most of the supply comes from Sicily and southern Italy.

Gambier.—Gambier or white cutch is a resinous substance extracted from the leaves and young branches of *Uncaria Gambir*, a climbing shrub of the Malay Peninsula and the Dutch East Indies. Under cultivation the plant becomes shrubby. The trees are cropped four times a year and the tannin is extracted from the tissues with boiling water. It crystallizes out as a

semisolid whitish substance. A considerable amount of gambier is exported to Europe and the United States, usually in the form of small cubes or larger blocks (Fig. 60). It has a tannin content

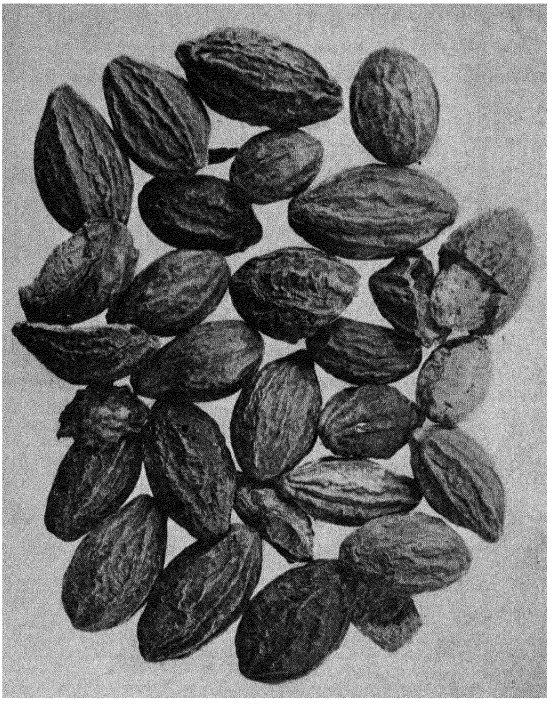


FIG. 59.—Myrobalan nuts, the unripe fruits of *Terminalia chebula* and a related species, are imported from India for use as a tanning material. (*Photo* by *S. J. Record.*)

of 35 to 40 per cent and is used for all kinds of leather. Gambier is also used as a dyestuff, as a masticatory, and in medicine.

Fruits

Myrobalan.—Myrobalan nuts are the unripe fruits of two species of Indian trees, *Terminalia chebula* and *T. Bellerica.* These trees have long been grown in India for both the fruits and the timber. The nuts (Fig. 59) have a tannin content of 30 to 40 per cent. When used alone they yield a spongy leather of a light-yellow color, but in combination they are more satis-

factory. They are used with calf, goat, and sheep skins, and for sole and harness leather.

Divi-divi.—This material is obtained from the dried twisted seed pods (Fig. 60) of *Caesalpinia coriaria*, a West Indian and South American legume. The product is very cheap and has a high tannin content, 40 to 50 per cent. In spite of this, only a small amount is used in the United States, although it is very popular in Europe.

Valonia.—The sun-dried acorn cups of the Turkish oak (*Quercus Aegilops*), a tree of Asia Minor and the Greek archipelago, furnish valonia. This material, which has a tannin content of 45 per cent, is used for the finer grades of leather, almost always in combination.

Roots

Canaigre.—Canaigre is an American tanning material obtained from the tanner's dock (*Rumex hymenosepalus*), a species native to the southern United States and Mexico. The plant is extensively cultivated. The roots are sliced and the tannin is extracted. Canaigre extract, with a tannin content of about 30 per cent, yields a bright-orange, firm, heavy leather.

Palmetto.—The roots of the palmetto (*Sabal Palmetto*) have been used to a slight extent as a source of tannin, but the content is too low, 10 per cent, to be of much value.

The Manufacture of Ink

Writing inks have been in use from the earliest recorded time. The Egyptians used ink on their papyrus as early as 2500 B.C., and the oldest Chinese writings go back at least to 2600 B.C. At first a carbon ink was used, a combination of charcoal, gums, and varnish. The charcoal was obtained from plant sources, such as charred date stones, or was of animal origin.

Tannin inks, which utilize the property that tannin has of combining with iron salts to give a blue-black color, are the most important kind today. These iron-tannin inks were first described in the eleventh century. Aleppo or nut galls (Fig. 60) have been the chief source of the tannin from the beginning. They were first used in 1393. These galls are formed on the twigs of the Aleppo oak (*Quercus infectoria*), as a response to the injuries caused by the egg-laying activities of an insect. The

plant is a small shrub, 5 or 6 ft. in height, found throughout the Mediterranean region. The small spherical or pear-shaped galls are produced in great abundance, and have an exceedingly high

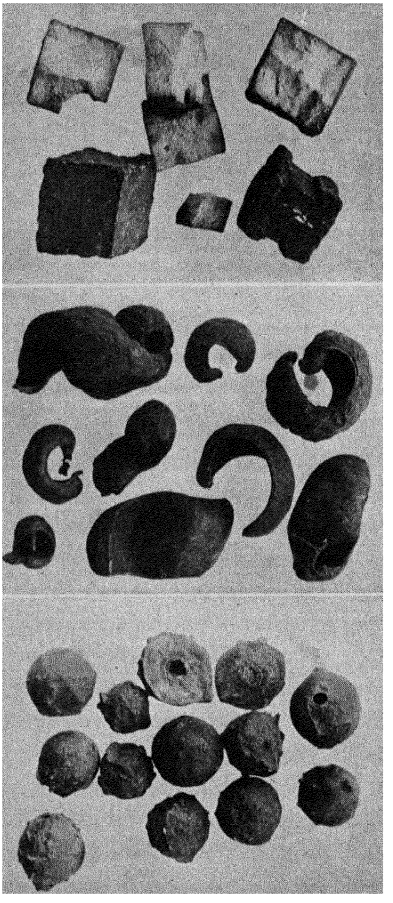


FIG. 60.—Three important sources of tannin. *Above*, cubes of gambier or white cutch obtained from *Uncaria Gambir; center*, divi-divi pods, the fruit of *Caesalpinia coriaria; below*, Aleppo or nut galls from *Quercus infectoria*. (*Photos by S. J. Record.*)

tannin content. In making ink, either the galls or an extract made from them are combined with ferrous sulphate; an agglutinant, such as gum arabic; and a coloring material, such as logwood or indigo. Similar galls produced on *Rhus chinensis*

and other Chinese and Japanese species of sumac are sometimes used as substitutes for Aleppo galls, although they are much inferior. During the World War these sumac galls were the only kind available.

Several other kinds of inks are manufactured. **Logwood inks** are made to some extent. Logwood is noteworthy because it contains both tannin and a coloring agent as well. **India ink** is made from soot, obtained from pine wood or rosin, and lampblack from oil of sesame, baked together with glue. **Colored inks** contain some of the natural dyestuffs, although aniline dyes are used for many of the cheaper grades The best red ink utilizes the coloring material in brazilwood **Printing inks** consist of a varnish made from linseed oil, rosin, and soap, mixed with a pigment and ground to a very fine state.

DYES AND PIGMENTS

Natural dyestuffs and stains, obtained from the roots, bark, leaves, fruit, or wood of plants, have been in use among all nations from earliest time. The cultivation of the plants and the preparation of the dyes have constituted an important industry in many countries. About the middle of the last century the natural products began to be supplanted by the synthetic or aniline dyes obtained from coal-tar products. These latter dyes were more permanent, cheaper, and afforded a wider range of colors. Their use has gradually led to the abandonment of most of the plant products.

Over 2000 different pigments are secreted by plants. The majority of these are used only locally by primitive peoples, if at all. A comparatively small number, about 130, have been of commercial importance, and of these a mere handful have been able to compete with the artificial colors.

The chief use of dyes has been in connection with the textile industry. Before they can be taken up by the fabrics, however, they must be rendered insoluble so they will not run. This is accomplished by the use of mordants, which are salts of various metals. When fabrics are steeped in a solution containing a weak salt of iron, chromium, aluminum, or tin, a fine layer of the metallic oxide is deposited on the cloth. The dye forms an insoluble compound with this oxide. Dyes are also used for coloring paints, varnishes, leather, ink, paper, wood, and medicines.

It would be too tedious a task even to list all the dyes that have been used in the United States at various times. The Indians made use of many native species and the early settlers followed the example of the Indians. Several dyes, not now in use, have been of importance. Butternut bark, for example, was used for dyeing homespun, and later for dyeing the uniforms of the Confederate army. As in other countries, most of the plant pigments have been generally supplanted by aniline dyes. For a while after 1914, when the World War cut off the supply of synthetic colors, 90 per cent of which were made in Germany, the United States returned somewhat to the use of the natural products.

Nearly all colors were available in one or another of the plant pigments. Red dyes were obtained from alkanna, barwood, brazilwood, cudbear, logwood, safflower, sappanwood, and sandalwood; yellow dyes from annatto, fustic, gamboge, henna, osage orange, Persian berries, quercitron, saffron, turmeric, and weld; blues from cudbear, indigo, and woad; greens from chlorophyll and lokao; and brown from cutch. These more important natural coloring materials will be considered according to their morphological nature.

Woods

Logwood.—Logwood is one of the oldest dyestuffs and one of the most important. At the present time it is used more than all the others together. The dye is obtained from the heartwood of *Haematoxylon campechianum*, a small, thorny, leguminaceous tree (Fig. 61) with peculiarly corrugated and clustered trunks. Logwood is a native species of Central America, but it has been introduced throughout the tropics. The United States obtains its supply from the West Indies and Central America. The trees can be propagated from seed and are now being cultivated to a considerable extent. They are cut when from 10 to 12 years of age and the bark and sapwood are removed. Either the logs or extracts are exported. The dye, of which as much as 40,000 tons has been made annually, has a purplish-red color. It is known as haematoxylin. It is used in its natural state or with a mordant. The presence of a considerable amount of tannin enables logwood extract to react with iron salts to give a black color, which is extensively used for dyeing cotton and

woolen goods. This black is the best and most lasting obtainable. As has been noted, logwood is also used in making some inks. Haematoxylin stain finds its greatest use in histological work. A related species, the brazilette (*H. Brasiletto*) furnishes a red dye.

Fustic.—Fustic is the principal source of natural yellows, browns, and olives, and it ranks next to logwood in importance. It is obtained from the heartwood of *Chlorophora tinctoria*, a tree of the dense tropical forests of Central and South America. The light yellowish wood turns a dark yellowish brown on exposure to the air. Fustic is exported in the form of sticks, chips, paste, or powder. This dye is often called *old fustic* to distinguish it from *young fustic*, a substitute obtained from the twigs of *Cotinus Coggygria*.

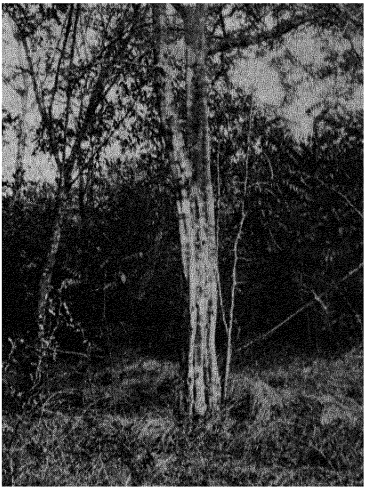


FIG. 61.—A logwood tree (*Haematoxylon campechianum*) in Haiti, showing the clustered and corrugated trunks. Logwood is an important dyestuff and tanning material. (*Photo by C. D. Mell; courtesy of S. J. Record*)

Cutch.—Cutch is a term used for several kinds of raw materials used both as dyes and in tanning. Gambier or white cutch has already been discussed. Black cutch or catechu is the source of the most important brown dye. It is obtained from the heartwood of *Acacia Catechu*, a tree of India and Burma. Small pieces of the wood are boiled in water and the extract is evaporated down to a purplish-black, gummy, semisolid substance, which is molded into blocks for export. The dye is strictly fast and is used for the various brown, fawn, olive, and drab colors, including the familiar khaki. Catechu is also used as a masticatory and in medicine.

Osage Orange.—The osage orange (*Maclura pomifera*) is a native tree of Arkansas, Oklahoma, and Texas, and is commonly planted elsewhere in the United States for ornamental purposes and for hedges. It is also one of the few native sources of

a dyestuff. The bright orange wood yields a dye that is used for orange-yellows and gold and as a base for greens. It was known to the Indians and in recent years has come into prominence as a substitute for fustic and the aniline dyes.

Sappanwood and Brazilwood.—These two red dyewoods have had an interesting history. The first red dyewood to be discovered was the heartwood of *Caesalpinia Sappan*, now known as sappanwood. This tree is a native of India and Malaya and cultivated elsewhere in the Asiatic tropics. The wood was introduced into Europe during the Middle Ages and was called "bresel wood." Later, when the Portuguese discovered a similar wood in South America, they naturally gave it the same name "bresel," and this name was also applied to the country in which the tree was found, *i.e.*, Brazil. The source of this New World brazilwood, as it is still called, is *Caesalpinia brasiliensis*, which occurs in tropical America and the West Indies. The heartwood yields a red dye used for cotton and woolen cloth and for red ink. The wood is a valuable material for violin bows. To some extent the bark and pods can be used as a source of the dye. Sappanwood has the same uses as brazilwood. In both cases the color is fugitive and the dyes are not much used today.

Barwood and Camwood.—A West African tree, *Baphia nitida*, is the source of these two dyewoods. They furnish a brilliant red color used in the United States chiefly for calico printing.

Red Sanderswood or Red Sandalwood.—*Pterocarpus santalinus*, an East Indian tree, has a hard, fragrant, reddish wood which is the source of a blood-red dye, known as red sanderswood or red sandalwood.

Leaves

Indigo.—Indigo or anil is still the "king of the dyestuffs." Nothing has been found to equal the permanency and strength of its deep-blue color. It is obtained from the Asiatic *Indigofera tinctoria*, the tropical American *I. suffruticosa*, and several other species of the same genus. The plants are stiff-stemmed, weedy-looking annuals or shrubby perennials. The indigo industry was formerly widespread and was even carried on in the Southern states at one time. Today indigo is extensively cultivated in India, Java, and Natal. Curiously enough, the dye is not present in the plant itself. The leaves contain a soluble colorless

glucoside, known as indican, which oxidizes in water to form the insoluble indigo. Fresh plants, collected in the flowering season, are broken up and steeped in water for 12 or more hours The liquid is constantly stirred to bring about complete oxidation, and the indigo gradually settles out as a bluish sediment, which is made up into small cubes for export. Indigo has been used as a dyestuff in India and other parts of the East from earliest time. It was introduced into Europe in the sixteenth century and soon spread all over the world. Synthetic indigo, which is easier to handle and apply, is used for poorer grades of cloth, where permanency is not essential.

Chlorophyll.—Chlorophyll, the source of the green color in plants, is obviously present in all green plants It is especially characteristic of the leaves of the higher plants, from which it can readily be extracted with various solvents. Chlorophyll is of increasing importance as a coloring material for foods, soap, and similar products. Its value lies in the fact that it is absolutely harmless.

Henna.—This orange dye is obtained from the leaves and young shoots of *Lawsonia inermis*, a small tree 6 to 8 ft. in height, found in Egypt, Arabia, Persia, and India. The branches are first cut when the tree is three years old, and thereafter twice annually. The leaves are dried and ground into a paste Henna is a very fast dye and is used chiefly for fabrics and leather. It is also used in many countries for dyeing the hair, eyebrows, and fingernails, and for other forms of personal adornment.

Woad.—One of the first blue dyes to be used in Europe was obtained from the leaves of the woad (*Isatis tinctoria*). This dye was used by the primitive Britons to paint their bodies. The leaves are moistened, slightly fermented, molded into balls, and dried. The plant is still cultivated to some extent.

Weld.—Weld is another old-time European dyestuff. It is a deep-yellow dye much used for silks. It is obtained from the leaves of the weld (*Reseda Luteola*), which was formerly cultivated throughout Europe. The plant was introduced into America by the early settlers, and still persists in many localities.

Roots and Tubers

Madder.—Madder was formerly one of the most important natural dyestuffs and was widely cultivated in all the Mediter-

ranean region. It is still grown in Italy and the Levant. The dye is obtained from the roots of the madder (*Rubia tinctorum*), which occurs as a wild plant in Greece, Asia Minor, and the Caucasus. An infusion made from three- or four-year-old roots shows a brilliant scarlet color, the familiar "turkey red." The coloring material is a glucoside, alizarin, which was one of the first to be made synthetically.

Alkanna.—The roots of *Alkanna tinctoria* yield a red or crimson dye which is used for coloring oils, pomades, medicines, and wines, and as a stain for histological work.

Turmeric.—Turmeric, one of the most important coloring materials of India, is obtained from the tubers of *Curcuma longa*. The natural dye is orange-red or reddish brown. It is much used to impart a yellow color to cloth and foods, such as curries. Turmeric also serves as a chemical indicator as it changes color depending on the presence of alkalies or acids.

Barks

Quercitron.—The crushed bark of the black oak (*Quercus velutina*), a familiar tree of the eastern United States, yields a bright-yellow dye known as quercitron. This is used for cotton and woolen goods with a tin mordant. Black-oak bark is also a tanning material.

Lokao.—Lokao or Chinese green is one of the few natural green coloring matters. It is a powdery substance made from the bark of two Chinese species of buckthorn, *Rhamnus globosa* and *R. utilis*. It is used chiefly for silks and cotton.

Flowers

Safflower.—The safflower (*Carthamnus tinctorius*), a very important dye plant, is a native of India, but is now widely distributed in most warm countries. It is one of the great tropical crops. Not only are the flowers (Fig. 62) used for a dye, but the seeds furnish an edible oil and the leaves are used as a salad vegetable. In India over 1,000,000 acres are planted to safflower. The plant is grown to some extent in the United States for the oil. The yellow or orange thistlelike heads are picked in dry weather, dried out, and pressed into cakes. Both a red dye, used for fabrics and rouge, and a yellow dye are

obtained. Safflower is grown commercially for the dye in southern France and Bengal.

Saffron.—The saffron crocus (*Crocus sativus*) is the source of this powerful yellow dye. This plant is a native of Greece and Asia Minor, but is cultivated in many parts of Europe and in

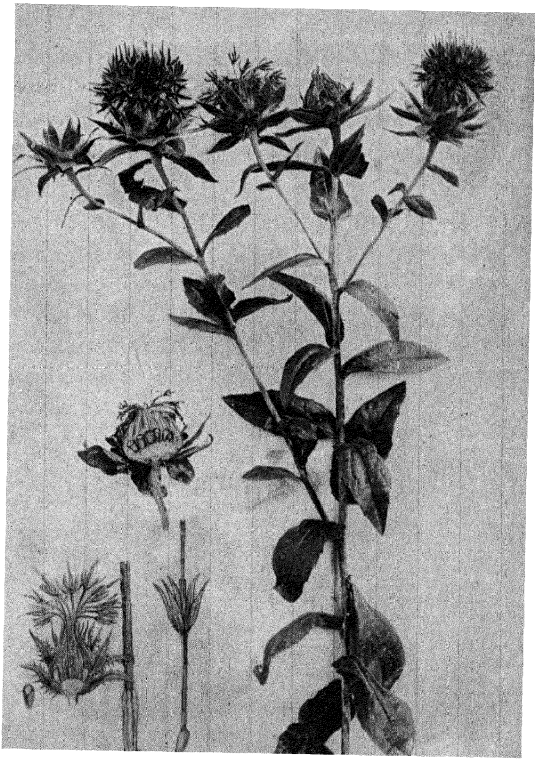


FIG. 62.—The leaves and inflorescence of the safflower (*Carthamnus tinctorius*). (*Reproduced from U.S.D.A. Circular* 366, *Safflower, A Possible New Oil-seed Crop for the Northern Great Plains and the Far Western States.*)

India and China as well. The blue or lavender flowers blossom in the fall. The stigmas and tips of the styles are used for the extraction of the dye. These are clipped as soon as the flowers open and are dried naturally or with artificial heat. It takes 4000 flowers to furnish an ounce of the dye. The coloring material is readily soluble in water so is not used for fabrics. It is, however, much used for coloring medicines and food.

Fruits

Persian Berries.—The unripe fruits of a buckthorn, *Rhamnus infectoria*, which grows in Southern Europe, Asia Minor, and Persia, are known as Persian berries. An extract of these berries yields yellow and green dyes of considerable use in European countries.

Sap Green.—Another native European buckthorn, *Rhamnus cathartica*, is the source of sap green. This water-color pigment is obtained from the fruits, which also have medicinal properties. This species has been introduced into the United States.

Seeds

Annatto.—This important coloring material comes from the seeds of *Bixa Orellana*, an evergreen bush or small tree (Fig. 63) native to tropical America. It is cultivated in many other tropical countries. There are few more satisfactory trees as regards growth and behavior. They begin to bear fruit the second year, and average 300 to 600 lb. to a tree. Each pod contains from 30 to 50 seeds, which are surrounded by a scarlet aril. This aril yields a bright-yellow dye. Either the seeds are exported or the aril is scraped off and made into a paste for shipment. Annatto is nearly tasteless, and so is well adapted for coloring butter, cheese, and other foodstuffs. It is also used for wool and calico goods, paint, varnish, lacquer, and soap. The Carib Indians used the dye to paint their bodies.

Gum Resin

Gamboge.—This yellow dye is obtained from a gum resin which is exuded from the Siamese gamboge tree (*Garcinia Hanburyi*) and allied species. These trees grow in Ceylon, Siam, and the East Indies. Incisions are made in the bark and a yellow viscid juice oozes out, which dries on exposure. It is usually collected in hollow bamboos, where it hardens into cylinders. The beautiful yellow dye is soluble in water, alcohol, or oil; it is much used by artists, and also gives a gold tinge to the varnishes used for lacquer and metalwork. Gamboge has a medicinal use as a violent cathartic.

Lichens

Archil and Cudbear.—This blue or purple dyestuff, known variously as archil, orchil, orseille, or cudbear, is obtained from several species of lichens, chiefly *Roccella tinctoria.* It was formerly used for silks, and is still utilized for staining wood and coloring wine. The dye is prepared by treating the lichens with

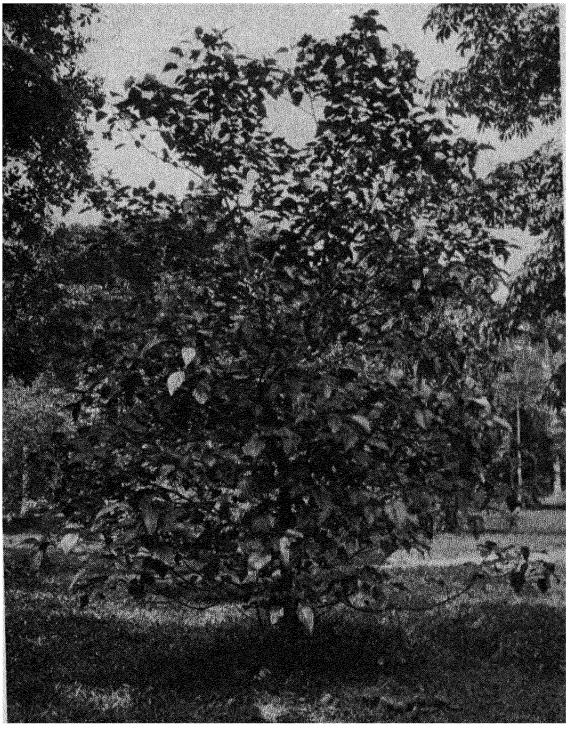


FIG. 63.—*Bixa Orellana.* An important yellow dye, annatto, is obtained from the aril that surrounds the seeds of this tropical American plant.

ammonia and exposing them to the air. A blue archil liquor is then extracted with water. When this is heated to drive off the ammonia, it changes to red archil. This is evaporated and ground to a fine powder, which is known as cudbear.

Litmus is obtained from the same lichens by a somewhat different process. They are treated with an alkali and allowed to ferment for several days. Lime is then added and the dye is

extracted with water. The liquid is evaporated down and mixed with chalk or powdered gypsum, or is applied to paper. Litmus is used as a chemical indicator for acids and alkalies, for its natural purplish color is changed to red by acids and to blue by alkalies.

1935 IMPORTS OF TANNING MATERIALS AND DYESTUFFS

Raw Materials

	Pounds		Pounds
Annatto	837,919	Myrobalan	27,498,240
Brazilwood	584,581	Nut galls	2,891,605
Cudbear	41,265	Quebracho	57,447,040
Divi-divi	88,096	Saffron	4,469
Fustic	4,386,008	Sumac	5,651,520
Gambier	4,484,120	Turmeric	1,168,711
Hemlock	361,000	Valonia	22,313,274
Logwood	25,500,160	Wattle	17,439,510
Mangrove	8,272,705		

Extracts

	Pounds		Pounds
Chlorophyll	23,775	Quebracho	110,438,725
Cutch	249,850	Sumac	5,864
Logwood	155,886	Valonia	2,803,470
Mangrove	17,360,685	Wattle	4,733,732
Myrobalan	2,957,613		

CHAPTER VI

RUBBER AND OTHER LATEX PRODUCTS

RUBBER

Rubber is obtained from the milky juice, or *latex*, of various erect or climbing woody plants of the tropics or subtropics. The majority of the rubber plants belong to the *Moraceae*, *Euphorbiaceae* or *Apocynaceae*. Although well over fifty species are available as sources, only a few are important commercially at the present time. Wild trees were formerly the only source, but now cultivated trees, the so-called plantation rubber, furnish about 95 per cent of the supply. Rubber is the most recent of the major crops of the world. The industry is only 100 years old, and cultivation has been carried on for but a little over 50 years. In view of this, the increase in the production of plantation rubber from 1000 tons in 1907 to over 300,000 tons in 1920 and over 620,000 tons in 1928 must be considered as one of the greatest triumphs in modern agriculture. This great development of the rubber-growing industry has not been without its drawbacks, however. Overproduction has seriously affected the industry financially in recent years, and many attempts have been made at some sort of regulation. The British, in particular, have tried to restrict production and exert other methods of control in Malaya and other plantation rubber centers within their empire. The recent successful development of synthetic rubber, after many years of experimentation, may further tend to jeopardize the natural rubber industry, for the new product is superior to the old in many ways.

Latex occurs in special cells or in a series of special vessels which permeate the bark, leaves, and other soft parts of the tree. Only the latex from the lower part of the trunk, and in some species from the aerial roots, is of importance commercially. Latex is a gummy white liquid full of minute globules. It is a mixture of water, hydrocarbons, resins, oils, proteins, sugar, and caoutchouc, the substance used as the source of rubber. The

significance of latex to the plant is not known. It may be of some value in the healing of wounds.

The properties of rubber have long been known. The primitive Central American Indians were familiar with it and called it "cahuchu," a name that has been changed to the present caoutchouc. Columbus was the first to report the existence of rubber to Europeans, but it was not introduced into Europe until 1735. The name "rubber" was first applied in 1770 by Priestley, owing to the fact that caoutchouc could be used for removing pencil marks. Mackintosh in 1823 developed a process for waterproofing cloth, but it was not until 1839, when the discovery of the vulcanizing process was made by Goodyear, that rubber really came into its own. From then on the rubber industry developed rapidly and today rubber has a vast number of uses and industrial applications.

The most important rubber-yielding species will be discussed in detail.

Para Rubber

The Para rubber tree (*Hevea brasiliensis*) is the source of from 90 to 95 per cent of the rubber produced throughout the world. This tree is a native of the hot damp forests of the Amazon and Orinoco river valleys in South America. It has been estimated that there are over 300,000,000 trees in this area, which covers 1,000,000 square miles. Within this region the optimum conditions for its development are found—a uniform climate with a temperature range from 75 to 90°F. and a rainfall of from 80 to 120 in. The trees may reach an age of 200 years, and may attain a height of 60 to 100 ft. and a girth of 8 to 10 ft. The leaves are three lobed, and the flowers are small and inconspicuous. The fruits contain three seeds, which contain 23 to 32 per cent of a fatty oil. This oil is sometimes extracted and used as a drying oil. The resulting oil cake is rich in proteins and is used as a stock feed. Rubber trees grow best on the flood plain islands, but they also occur on the uplands.

Wild Rubber.—The collecting of the latex is in the hands of natives, called *seringueros*, who are in the employ of the owners of the rubber estates. After suitable trees have been located, cuts are made in the bark with an ax or some other instrument. Cups are placed below the cuts to receive the latex, which flows

for several hours. It is then collected in larger vessels and transported to the camp for coagulation. Fires are built of palm nuts, which yield a dense smoke, containing acetic acid, creosote, and tars. Paddles are dipped in the latex and held in this smoke, which coagulates the milk, and gradually a layer of crude rubber forms. This process is repeated until a large ball of rubber, weighing from 20 to 100 lb., is obtained. This crude



FIG. 64.—Tapping a Para rubber tree (*Hevea brasiliensis*) on a plantation in India, using the spiral-cut method.

wild rubber is rather impure and contains 15 per cent of water. Rubber is occasionally obtained from other species of *Hevea*.

Plantation Rubber.—Para rubber has now been introduced into all the tropical countries where the rain-forest type of vegetation can develop, and the tree is extensively grown under plantation conditions (Fig. 64). In 1929 over 6,000,000 acres were under cultivation, chiefly in Ceylon, Malaya, Java, and Sumatra. Every step in the production of plantation rubber has been carefully investigated and the best methods of planting, cultivation, tapping, and coagulation are practiced. Under

plantation conditions rubber will grow at an altitude of 2000 ft. Rubber trees are propagated from seed in nurseries and are then transplanted. Occasionally grafting or budding is resorted to. The trees grow rapidly and can be tapped when five years of age. Older trees, however, have the best yield.

There are several methods of *tapping*. In the herringbone method oblique cuts are made leading to a central vertical cut. One-sided and spiral cuts are also used. In all cases an attempt is made to cut as many latex vessels as possible and to go near enough to the cambium to bring about a wound response, which increases the yield. The trees are tapped throughout the year, usually in the morning, and in wet weather if possible. Mallets and chisels are the instruments used. Thin slices are taken off the cuts each day until they are 1½ in. wide, after which they are allowed to heal. The latex runs for about half an hour after the cuts have been reopened and it is caught in aluminum cups. The yield may be as much as 25 lb. Eventually the latex is strained to remove any impurities and water or formalin is added.

Various methods of *coagulation* are resorted to. Usually the latex is poured onto enameled iron plates, and acetic acid is added. The plates are covered and set aside for 12 hours, during which time the rubber coagulates. The cake is then removed, rolled flat, and dried for several weeks. The resulting *biscuits* are then packed for shipment. *Sheet rubber* is made by rolling the coagulated latex in mills to form thin sheets; *worm rubber* consists of irregular wormlike pieces cut from sheets with a pair of shears. Much crude rubber is shipped as *crepe rubber*. This is prepared in tanks, where the irregular mass of coagulated latex is bleached and washed. It is then passed through a creping machine which turns out long, thin, perforated strips of rubber. These are air dried. Ammonia, formic acid from ants, cigar smoke, and wood smoke are sometimes used as coagulating agents. In recent years considerable latex is converted into *sprayed rubber*. In this process latex is dropped on whirling disks and little particles of rubber are thrown off; any moisture quickly evaporates. This type of rubber has the advantage of being exceedingly pure and clean. At the present time much liquid latex is imported into the United States. This contains ammonia, which is added to preserve the latex and prevent coagulation.

Panama Rubber

Panama rubber is obtained from *Castilla elastica*, a tall native tree of Mexico and Central America. It has been known, under many local names, since 1794, and has been used as a source of rubber since 1875. Probably several species of *Castilla* are



FIG. 65.—The base of a Panama rubber tree (*Castilla elastica*), showing incisions and methods of collecting the latex.

involved. The tree grows in deep loamy soil on high ground and may reach a height of 150 ft. It requires a temperature above 60°F., and must have shade when young. Formerly the trees were cut down in order to obtain the largest possible yield of latex. This wasteful method almost led to the extermination of the species, and today more conservative methods are in use. The trees are tapped (Fig. 65) when 8 to 10 years of age, and

yield up to 50 lb. The latex is coagulated with plant juices, alum, and by boiling or exposure to the air. The crude rubber is shipped in flat cakes. Panama rubber is now being extensively cultivated in Central America under plantation conditions, but it cannot successfully compete elsewhere with Para rubber.

Ceara Rubber

Ceara rubber is obtained from *Manihot Glaziovii*, a small tree (Fig. 66) native to the desert regions of Brazil. It grows well in



FIG. 66.—The Ceara rubber tree (*Manihot Glaziovii*) growing in Ceylon.

dry rocky ground, and so can be utilized in areas unsuitable for other types of rubber. The tree grows very rapidly, reaching its maximum height of 30 ft. in a very few years. Ceara rubber is now grown in Ceylon, India, and many other tropical countries. The trees are tapped when four or five years of age and yield a good grade of rubber. The latex is coagulated by exposure to air or smoke. The crude rubber is exported as blocks or flat cakes.

Assam Rubber

Assam rubber, or India rubber as it is more familiarly called, is obtained from *Ficus elastica*, a native tree of northern India

and Malaya. The tree requires a hot climate and a large amount of rainfall. It often starts life as an epiphyte. It grows to a great height, developing huge buttresses or prop roots (Fig. 67). Our familiar greenhouse plants resemble young wild plants. The roots as well as the stem are tapped. The latex is allowed to drip onto bamboo mats, where it coagulates. A large amount coagulates on the trunk as well. This crude rubber is scraped



FIG. 67.—An India rubber tree (*Ficus elastica*) in Colombo, Ceylon, showing the huge buttresses and prop roots.

off, cleaned, and dried. The native methods of tapping the wild trees have been very wasteful, so the tree is now cultivated to some extent. The yield is low and the trees do not mature until about 50 years of age. Assam rubber is of low grade and is of little or no commercial importance at the present time.

Lagos Silk Rubber

Lagos silk rubber comes from *Funtumia elastica*, a large tree of tropical West Africa. It was discovered in 1894, but was immediately exploited by such wasteful methods that it has been nearly exterminated. In 1898 over 6,000,000 lb. were exported. The tree is now being cultivated and an attempt made

to reestablish the industry. Plantations of Para rubber, however, are the chief source of rubber as far as West Africa is concerned.

Landolphia Rubber

Other former sources of African rubber were several woody climbers belonging to the genus *Landolphia*. The most important of these were *L. Kirkii* on the east coast and *L. Heudelotii* and *L. owariensis* on the west coast. These huge vines, sometimes 6 in. in diameter, were pulled down and cut into small pieces. The latex that exuded was coagulated with plant juices or the heat of the sun, sometimes even on the bodies of the native collectors. The most wasteful methods were employed, for a large immediate yield was all that was desired. The worst feature in connection with this particular rubber industry, however, was the barbarous treatment of the natives. The story of the operations in the Belgian Congo during the reign of Leopold II will always remain one of the blackest pages in history. Although there is still a considerable amount of wild landolphia rubber, there seems to be but little future for it, for the African natives are the most ignorant of all rubber collectors and cannot be taught proper methods of tapping. Furthermore cultivation is impracticable owing to the habit of the plant.

Guayule Rubber

The guayule (*Parthenium argentatum*), a native American species, is the only nontropical plant to be utilized as a source of rubber. This low semishrubby plant (Fig. 68) grows in the arid regions of Mexico and the southern United States. It was known to the early Indians, who obtained the caoutchouc by chewing the plants. Unlike the other sources of rubber, there is no latex present in the guayule plant, but little granules of caoutchouc are scattered all through the tissues. These are extracted mechanically or by means of solvents. Much washing is then necessary and the resulting rubber is poor in quality and yield. However, guayule rubber is well adapted for certain purposes and its use is increasing. One handicap is the necessity of completely destroying each crop in order to obtain the caoutchouc, a condition that does not occur in the latex-containing

species. It is possible to treat guayule as a crop plant and its cultivation is increasing.

Minor Sources of Rubber

Many other species of plants have been experimented with as a possible source of rubber. Prominent among these may be mentioned intisy (*Euphorbia Intisy*). This leafless shrub of the arid regions of Madagascar contains a latex that has had considerable use locally. The rubber coagulates on the surface of the plant in long elastic strands and is of high grade. Attempts

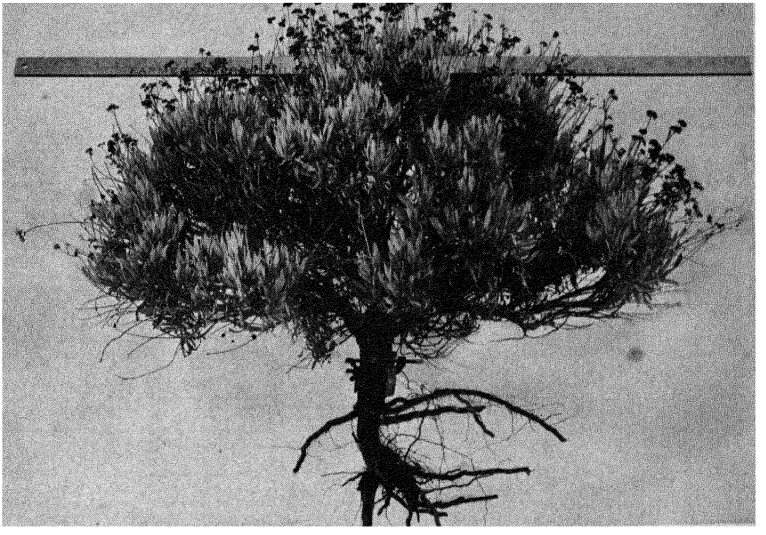


FIG. 68.—A mature guayule plant (*Parthenium argentatum*), the only important source of rubber native to the United States.

are being made to cultivate intisy in the United States, for it is well adapted to the desert conditions of the Southwest.

Several native American plants have been utilized to some extent. The desert milkweed (*Asclepias subulata*), the Indian hemp (*Apocynum cannabinum*), and more recently several goldenrods, particularly *Solidago Leavenworthii*, have been tried out. In the latter plant the caoutchouc occurs in the form of granules. This plant offers considerable hope of its becoming important and the experiments initiated by Thomas Edison are being continued.

Production and Use of Rubber

In 1933 the world's trade in crude rubber amounted to nearly 2,300,000 lb. British Malaya led in exports with 1,300,000 lb., followed by the Dutch East Indies with 750,000 lb. and Ceylon with 142,000 lb. Other important producing countries were Indo-China, Borneo, Brazil, and India.

The United States is the greatest consumer of rubber, using about two-thirds of the total output. Great Britain, France, and Germany are next in order. Great Britain, however, uses only about one-quarter as much as the United States.

Rubber is one of the most indispensable of plant products and it has a wider range of industrial uses than any other material. Over 85 per cent of the crude rubber is used for tires and inner tubes. Other uses include rubber boots and shoes; mechanical goods such as hose, tubes, and belting; waterproof clothing; druggist's supplies; insulated wire and other electrical goods; toys; machine packing; and cements. Hard rubber, which is prepared by vulcanizing crude rubber with 30 per cent sulphur, has many additional uses and is especially valuable for surgical appliances and telephone and radio parts.

GUTTA-PERCHA

Gutta-percha is a nonelastic rubber obtained from the grayish-white latex of several members of the *Sapotaceae*. The chief source is *Palaquium Gutta*, a tree of Malayan origin which now grows in Borneo, Sumatra, the Philippine Islands, and other tropical countries as well. The latex is produced in sacs, which occur in the cortex, phloem, pith, and leaves. It is obtained by making incisions from which the milky juice runs out very slowly, or by felling the trees (Fig. 69). This latter is the more usual method. The bark is removed in strips 1 in. in width and 1 ft. apart, and the latex is caught in coconut shells or in palm or plantain leaves. The latex soon coagulates into grayish-yellow masses of a hard substance, which is odorless and heavier than water. This crude product contains several resins and other impurities, and is purified by washing in hot water. The whole mass is boiled and then kneaded into blocks, or it is chopped or sliced up and the pieces are washed, strained and kneaded, and then rolled into thin sheets. The value of gutta-

percha depends on the amount of a hydrocarbon, gutta, that is present.

Gutta-percha is hard at ordinary temperatures. It deteriorates very rapidly in the air through oxidation and should be kept under water. It softens at 77°F., can be kneaded at 122°F., and melts at 248°F. Because it is an exceedingly poor conductor of electricity it is much used for insulation. No other material



FIG. 69.—A gutta-percha tree (*Palaquium Gutta*) felled and ringed. This is a very destructive method of obtaining the latex. (*Photo by the Philippine Bureau of Forestry.*)

can replace gutta-percha and the similar balata in the construction of submarine cables, which require a substance that is resistant to salt water, pliable, and with just the right amount of rigidity. Other uses include splints, supports, pipes, golf balls, speaking tubes, telephone receivers, waterproofing, and adhesives. It is also utilized for protecting wounds and in dentistry. Although little known outside a limited circle, gutta-percha is indispensable in the world's work. It has been known since 1842.

BALATA

Balata is a nonelastic rubber that is obtained from the latex of *Manilkara bidentata*, formerly known as *Mimusops Balata*.

This species is a native of Trinidad and South America. It is a magnificent tree which grows to a height of over 100 ft. When mature, its purplish wood is very hard and durable and is much used for ties and building purposes under the name of bully wood or bulletwood. The fruit is edible. The latex is obtained by tapping the trees three times each year. It flows freely and readily coagulates in the air. A tree 3 ft. in circumference will yield from 50 to 100 lb. of dry balata. After coagulation it is cleaned and molded into cakes. Balata contains about 50 per cent of gum. It serves the same purpose in industry as does gutta-percha. It is particularly well adapted for machine beltings as it grips tightly and never stretches. It is also used as a substitute for chicle. Balata has been known since 1859. Unlike gutta-percha, it has never been cultivated and probably will always remain a wild crop.

JELUTONG

Jelutong is obtained principally from *Dyera costulata* and related species. These Malayan trees have an astonishing flow of latex, greater than all the other latex species together. From 1910 to 1915 this material was exploited as a source of rubber. The latex, however, is full of gums, resins, and other impurities, and it yielded such a poor grade of rubber that it was soon discarded. Jelutong is now used as a substitute for chicle.

CHICLE

The sapodilla or naseberry (*Achras Zapota*) is a tall evergreen tree, a native of Mexico and Central America. It is cultivated in tropical America and Florida for its edible fruit. The bark contains a latex, 20 to 25 per cent of which consists of a gutta-percha-like gum. This gum is known as chicle, and is the basis of the chewing-gum industry.

The most primitive method of obtaining the chicle is to tap the trunk and then scrape the thickened exudate from the bark. The crude or loaf chicle consists of pink or reddish-brown pieces mixed with 25 to 40 per cent of impurities. In southeastern Mexico and British Honduras, where the industry is carried on most extensively, the native collectors, or *chicleros*, are more careful. Zigzag gashes are cut in the trunk with machetes, up to a height of 30 ft. The latex runs to the base of the tree

where it is collected in rubberized bags (Fig. 70), leaves, or even hollows in the earth. This accounts for the grains of sand that are sometimes found in chewing gum. The flow of latex lasts for several hours and the yield may be as much as 60 qt. In order to conserve the supply, plantations are now being established. These are not very practicable, however, for the trees can be tapped only every two or three years.

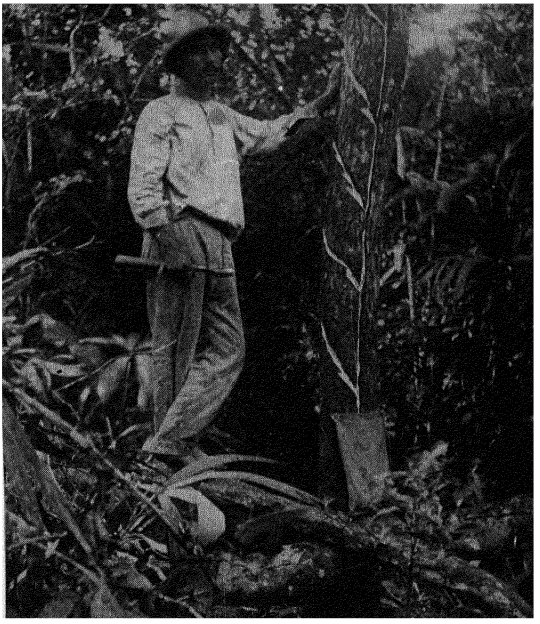


FIG. 70.—Collecting the latex from a sapodilla (*Achras Zapota*). This latex contains chicle, the basis of the chewing-gum industry. (*Photo by H. M. Heyder; courtesy of S. J. Record.*)

The hardened chicle is boiled, a process that requires considerable skill, for the chicle must be poured off when the moisture content reaches 33 per cent. It is then molded into blocks for shipment. Raw chicle contains resin, gutta, arabin, calcium, sugar, and various soluble salts. It is purified by being broken into small pieces, washed in a strong alkali, neutralized with sodium acid phosphate, washed again, and then dried and powdered. The final product is an amorphous pale-pink powder. This is insoluble in water and forms a very sticky mass when

heated. As it ages it is partially oxidized, turns brown, and becomes very brittle. The final steps in the manufacture of chewing gum involve cleaning, filtering, sterilizing, and compounding with various flavoring materials. Thirteen pounds of chicle, as it comes from the final processing, makes about 5000 pieces of chewing gum. A piece of chewing gum usually contains about 15 per cent chicle, the remainder being chicle substitutes, sugar, and flavoring substances. Many attempts have been made to discover natural or synthetic gums that might be used as substitutes for chicle. Inferior latex from other sapodillas and jelutong are both used somewhat. The United States is the great chewing-gum nation and uses almost the entire output of chicle. The supply is imported chiefly from Belize in British Honduras.

OTHER LATEX TREES

Several species of latex trees have been reported from South and Central America in which gummy and resinous substances are almost entirely lacking and the latex can be used as a substitute for milk. The first of these "cow trees," now identified as *Brosimum utile*, was described by Alexander von Humboldt in 1800 from the coastal mountains of Venezuela. He reports the natives as visiting the trees early in the morning and either drinking the milk on the spot or taking it to their huts, where they dipped their cassava bread in it. Pittier reports similar trees, belonging to the genus *Mimusops*, from Costa Rica and Guatemala, with a sweet and rather palatable latex used by the natives as a remedy for stomach disorders. More recently Record discovered a cow tree while collecting near Entre Rios in Guatemala. At the first stroke of the ax there was a remarkable flow of milk, impressing even the natives. When the tree fell, there were many breaks in the bark through which the milk actually bubbled up. It was hot and sticky, but sweet and palatable, and deserves consideration as a possible substitute for mammal's milk. The latex contains some chicle and has been suggested as a substitute for the true chicle. This latter species of cow tree has been identified as *Couma guatemalensis*.

1935 IMPORTS OF RUBBER AND OTHER LATEX PRODUCTS

	Pounds		Pounds
Balata	1,277,273	Jelutong.	12,643,496
Chicle	7,775,221	Rubber, crude	1,015,020,761
Guayule.	1,028,400	Rubber, latex	30,358,748
Gutta-percha	3,588,728		

CHAPTER VII

GUMS AND RESINS

GUMS

The true gums are formed as the result of the disintegration of internal tissues, for the most part from the decomposition of cellulose, through a process known as gummosis. Gums contain a large amount of sugar and are closely allied to the pectins. They are soluble in water, either dissolving completely or swelling, but are insoluble in alcohol and ether. They exude naturally from the stems, or in response to wounding. The commercial gums reach the market in the form of dried exudations. Gums are especially common in plants of dry regions. They find their greatest use as adhesives, and are also used in calico printing, as a sizing for paper, in the paint and candy industries, and as drugs. The two most important commercial gums are gum arabic and gum tragacanth.

Gum Arabic.—This is a dried gummy exudation obtained chiefly from *Acacia Senegal*, a small native tree of arid Northern Africa. This species is extensively cultivated in the Sudan. The trees are tapped between February and May, when the fruits are ripe. Transverse incisions are made with a small ax (Fig. 71) and thin strips of the outer bark are torn off. The gum slowly exudes as a viscous liquid, collects in a drop, and hardens. After three to eight weeks these "tears" are collected. They are bleached by the sun, and the impurities are removed before shipping. This Sudan gum has been known since 100 A.D. Several kinds reach the world's markets. Kordofan or hashab gum is exported from the region around Cairo and Port Sudan, while Senegal gum comes from the Senegal River. Gum arabic is slowly soluble in cold water and has a high degree of adhesiveness and viscosity. Most of it is used in the textile, mucilage, paste, polish, and confectionery industries, and as a glaze in painting. In medicine it is used as an emulsifying agent and as a demulcent.

Gum Tragacanth.—This gum forms as a result of the transformation of the pith and medullary-ray cells into a mucilaginous substance that exudes naturally or after the bark has been punctured or excised. It comes from *Astragalus gummifer*, a thorny shrub of Western Asia and Southeastern Europe. The gum is allowed to dry on the bark before it is collected. It

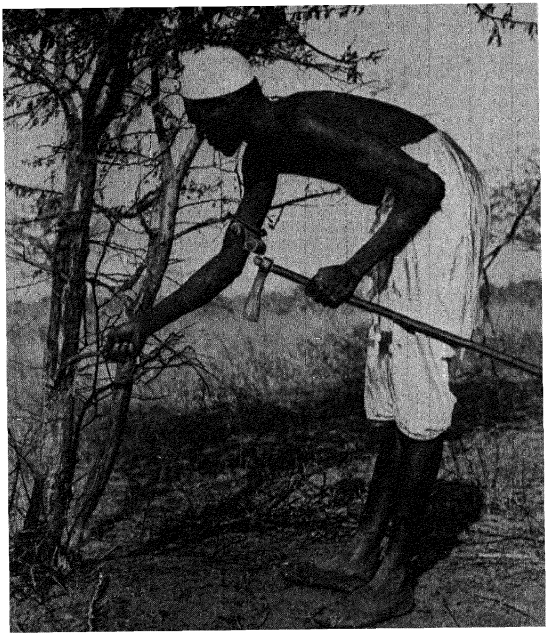


FIG. 71.—A native tearing away the bark of a gum-arabic tree (*Acacia Senegal*) so that the gum may exude. The gum-arabic industry is carried on in the Sudan and other regions of Northern Africa. (*Reproduced by permission from Toothaker, Commercial Raw Materials, Ginn and Company.*)

reaches the market in one of three forms: tears, which are the dried natural exudation; vermiform gum, which consists of narrow twisted coils or strings; and flakes, which are ribbonlike pieces. Most of the commercial supply comes from Baghdad, to which city it is carried by caravans from all over Persia. Gum tragacanth is used in calico printing and for other industrial purposes. It is valuable in medicine, serving as an adhesive agent for pills and troches and for the suspension of insoluble powders.

Kadaya Gum.—This gum has become very important in recent years and several million pounds are imported annually from India. Various Indian trees yield gummy substances known as kadaya, karaya, katira, kuteera, bassorin, and other vernacular names. The chief sources seem to be *Sterculia urens* and *Cochlospermum Gossypium.* Kadaya gum is used chiefly in the cigar, paste, and ice-cream industries.

Other Gums.—Many other plants, chiefly tropical, yield gums of some commercial importance. Among these may be mentioned gum ghatti from *Anogeissus latifolia*, an Indian tree; and feronia gum from *Feronia Limonia* of India, Burma, and Java, both of which are used as substitutes for gum arabic. Cycas gum from the Asiatic *Cycas circinalis;* tragasol, a mucilaginous substance present in the pods of the carob (*Ceratonia Siliqua*) and much used in textile sizing; mesquite gum from *Prosopis chilensis*, *P. glandulosa*, and other species; and cherry gum from various species of *Prunus* are all valuable.

RESINS

Resins represent oxidation products of various essential oils and are very complex and varied in their chemical composition. The resin is usually secreted in definite cavities or passages. It normally oozes out through the bark and hardens on exposure to the air. Commercial resins are often collected from artificial wounds or from fossil material. Resinous substances may occur alone or in combination with essential oils or gums. Unlike gums, resins are insoluble in water, but dissolve in ether, alcohol, and other solvents. Resin production is widespread in nature, but only a few families are commercially important. These include the *Anacardiaceae*, *Burseraceae*, *Dipterocarpaceae*, *Guttiferae*, *Hamamelidaceae*, *Leguminosae*, *Liliaceae*, *Pinaceae*, *Styracaceae*, and *Umbelliferae.* It is often difficult to trace the exact botanical origin of a resin, especially in the case of fossil and semifossil types.

Resins are probably of some service to the plant by preventing decay. This is due to their high antiseptic qualities. They may also tend to lessen the amount of water lost from the tissues.

Resins possess certain characteristics that render them of great importance in industry. Their ability to harden gradually, as the oil that they contain evaporates, makes possible commercial

varnishes. The resins are dissolved in solvents, and surfaces are then painted with the mixture. As the solvents and oils evaporate, a thin waterproof layer of the resin is left. Resinous substances have been utilized for waterproof coatings, and also for decorative coatings, for ages. The ancient Egyptians varnished their mummy cases. The utilization of lacquer in the arts has been practiced in China and Japan for centuries. The Greeks and Romans were familiar with many of the same resinous materials that are in use today, as, for example, amber, mastic, and sandarac. Another property of resins that is of industrial importance is their ability to dissolve in alkalies to form soap. Resins are also used in medicine; for sizing paper; as a stiffening material for mats; in the preparation of sealing wax, incense, and perfumes; and for many other purposes.

The classification of resins is in a very chaotic condition. The same term is often used for very diverse materials In the trade, resins are often referred to as gums, while such terms as varnish resins, hard resins, spirit varnishes, balsams, gum resins, damar resins, soft resins, and many others are used more or less indiscriminately. The chemical differences between the various groups are much more definite. For our purposes we shall distinguish three groups: the hard resins, oleoresins, and gum resins.

HARD RESINS

The hard resins contain only a little, if any, essential oil. They are usually solid, more or less transparent, brittle substances with no particular odor or taste. They are readily fusible and burn in air with a smoky flame. They are nonvolatile and are very poor conductors of electricity. When friction is applied, they become negatively electrified. The hard resins constitute the best source of varnishes, owing to their low oil content and the readiness with which they dissolve in alcohol. The most important commercial resins, such as the copals and damars, belong to this group.

Copals

The copals comprise a considerable group of resins of recent, semifossil, and fossil origin, which are found in many tropical and subtropical countries. The word "copal" is of Mexican

origin. Many of the harder copals are known as animés, especially in England. The copals contain almost no oil, and yield a hard elastic varnish, which is much used for outdoor work. Several types are known which are quite diversified in character and source.

East African Copals.—*Zanzibar copal* and the closely allied *Madagascar* and *Mozambique copals* are derived from *Trachylobium verrucosum.* Zanzibar copal is the hardest of all resins except amber and is very valuable. The resin exudes naturally from the trunk, branches, and fruit. Most of the commercial supply, however, is obtained from semifossil material, derived from still living trees, and fossil material from trees that no longer exist. This fossil copal, as it is dug from the ground, is covered with a crust of oxidized material. After this has been removed, the copal shows a characteristic surface, known as "goose skin," which consists of large and small excrescences. The interior is clear and transparent and varies from yellow to brownish red in color.

Inhambane copal, of little commercial importance, is obtained from *Copaifera Gorskiana,* a valuable timber tree of the Southeast African coast.

West African Copals.—The West African copals include a considerable number of hard resins, and are usually designated by the name of the region from which they are obtained. The most important of these are the Congo, Angola, Sierra Leone, Accra, and Benin copals.

Congo copal is the most important of the West African copals and has been extensively exploited in recent years. It is derived from *Copaifera Demeusii* and *C. mopane,* which are characteristic trees of the Congo basin. Although living trees furnish some of the supply, the greater part is obtained from the ground or from water courses, and is more or less fossil in nature. The white and red *Angola copals* are derived from the same two species.

Sierra Leone copal is a light-yellow, hard, and brittle resin that is obtained from *Copaifera Guibortiana* and *C. Salikounda.* Living trees are wounded and the resin exudes and hardens in the form of globular tears. Some fossil material is also obtained. Because of the value of this copal, the trees are protected by the Sierra Leone government.

Accra and *Benin copals* are probably derived from *Daniella Ogea* and related species. These large trees are found in the coastal forests of Liberia, the Gold Coast, and Nigeria. The resinous exudation, known locally as ogea gum, is becoming increasingly important as a varnish resin.

Kauri Copal.—Kauri copal or kauri gum is one of the most valuable of the hard resins. It is obtained from the kauri pine



FIG. 72.—The kauri pine (*Agathis australis*), New Zealand's largest and most important tree, is the source of kauri copal, one of the most valuable of the hard resins.

(*Agathis australis*), which is New Zealand's largest and most important tree (Fig. 72). The copal is chiefly fossil in nature and is dug up on ridges and in swamps and boggy ground. "Swamp gum" furnishes the bulk of the supply, and ranges in size from pieces 1 or 2 in. in diameter to lumps weighing 100 lb. "Range gum" yields the best grade of kauri. An inferior "bush gum" is obtained by tapping living trees. Kauri is yellow, transparent, and very hard. It is an exceedingly valuable varnish resin, especially for marine and outside work. It

is also used in making linoleum. Kauri constitutes one of the chief exports of New Zealand, and the industry is controlled by the government.

Manila Copal.—The first shipments of this important copal were made from Manila and the name has persisted, although today 75 per cent of the product is shipped from the Dutch East Indies. The source of all the East Indian, Philippine, and Malayan copals, of which there are many different kinds, is *Agathis alba*. This tall conifer, which reaches a height of 200 ft., is a characteristic tree on high ground. The resin exudes naturally, and is also obtained by systematic tapping. Some of the supply is derived from fossil material and consists of large, irregular, angular, milky pieces with a yellowish interior. Hard, semihard, and soft copals are included among the many different kinds in the trade. Pontianak copal from Borneo is the hardest variety and is especially popular in the United States. Manila copal varnishes are durable, but they do not adhere strongly to surfaces and they are not very brilliant. They are used chiefly for interior work and enamels. These copals are often erroneously called damars, although they are quite distinct from the true damars.

South American Copals.—The South American locust (*Hymenaea Courbaril*), a tall tree of Brazil and other parts of tropical America, is the chief source of the South American copal. The stems, twigs, and even the fruits exude a large amount of resin, which trickles to the ground. The commercial resin is collected from the base of living trees, and former trees as well, and is marketed as Demerara, or Para copal. It is the softest of all copals, and consequently the least valuable.

Damars

Considerable confusion exists in regard to the application of the term "damar." The word is of Malayan origin, and is used by the natives to indicate a torch made of decayed wood and bark, mixed with oil and powdered resin, wrapped in leaves, and bound with strips of rattan. Originally it did not refer to any specific tree or resin. Gradually the word came to be a collective term for a great variety of hard resins of quite different origin, and included even kauri and manila copal. In the commercial trade, however, the term "damar" is practically restricted to resins

that are obtained from members of the *Dipterocarpaceae*. A few resins from species of the *Burseraceae* are included. This distinction should be maintained, for the true damars are very different chemically from the various coniferous resins. For example, unlike Manila copal, damar is insoluble in chloral hydrate, but completely soluble in alcohol and turpentine.

The trees that yield damars (Fig. 73) are characteristic of all Southeastern Asia, and are particularly abundant in Malaya and Sumatra. Although all members of the *Dipterocarpaceae* secrete resin, comparatively few species are of commercial importance. These are found chiefly in the genera *Balanocarpus*, *Hopea*, and *Shorea*. Damars are especially important in Malaya and are obtained by tapping the trees. The most important Malayan varieties are Damar Mata Kuching from *Hopea micrantha* and related species, Damar Penak from *Balanocarpus Heimii*, and Damar Temak from *Shorea crassifolia*. The principal damars of India are sal damar from *Shorea robusta*, white damar from *Vateria indica*, and black damar from *Canarium strictum*. Damars are also produced in Borneo, Java, Sumatra, Siam, and Cochin China. The most outstanding commercial variety of damar is the so-called Batavian damar, a product of *Shorea Wiesneri*, a species found in Java and Sumatra.

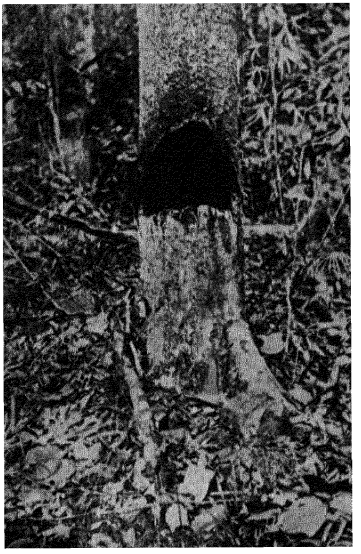


FIG. 73.—A dipterocarpus tree boxed for gathering the resin known commercially as damar. (*Photo by the Philippine Bureau of Forestry.*)

Damars are used chiefly in spirit varnishes and the manufacture of nitrocellulose lacquers. Damar varnishes adhere better than Manila copal varnishes, but are softer and less durable. They are particularly well adapted for varnishing paper because of their luster and light color. They are also used for indoor work and in histology.

Amber

Amber is a fossil resin found chiefly along the shores of the Baltic Sea. The principal source of Baltic amber was the now extinct pine, *Pinus succinifera*, a species that flourished on the shores of a former sea in Eocene time. Amber is an exceedingly hard and brittle substance. It occurs in several forms, the most important of which is succinite. Some of these forms are transparent and others are almost opaque. The color varies from yellow to brown and even black. When rubbed, amber

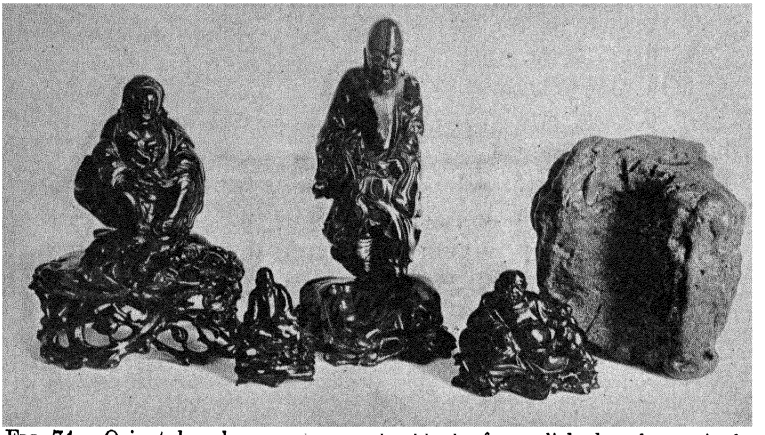


FIG. 74.—Oriental amber carvings and a block of unpolished amber. Amber is a fossil resin, secreted chiefly by the now extinct *Pinus succinifera*. (*Courtesy of the Botanical Museum of Harvard University.*)

takes on a high polish and becomes negatively electrified. It also gives off a characteristic aromatic odor. Amber has been known for thousands of years. The Swiss Lake Dwellers were familiar with it, and it was highly prized by the Greeks and Romans. It has always been used for beads and other ornamental purposes, and is often carved (Fig. 74). Today the chief use of amber is for the mouthpieces of pipes and holders for cigars and cigarettes. The darker grades yield a valuable varnish, but it is too expensive to be used much. Amber is also used to increase the elasticity of rayon fibers and as the source of an essential oil. Scientifically amber is of interest for there are often found imbedded in it the remains of plants, insects, and other objects which existed at the time the fresh resin was exuded from the pines.

Lacquer

Lacquer is a natural varnish that is exuded from various Asiatic trees, and enormous quantities of it are used in oriental countries for ornamental purposes. The principal source is the lacquer tree (*Rhus verniciflua*), a native of China, but long cultivated in Japan. The trees are carefully cultivated and systematically tapped. The exudation is a milky liquid which darkens and thickens rapidly on exposure. It can be kept unchanged, however, for long periods by storing in closed containers. Before use it is filtered. When applied as a varnish, the thin film rapidly hardens in a moist atmosphere, owing in part to oxida-

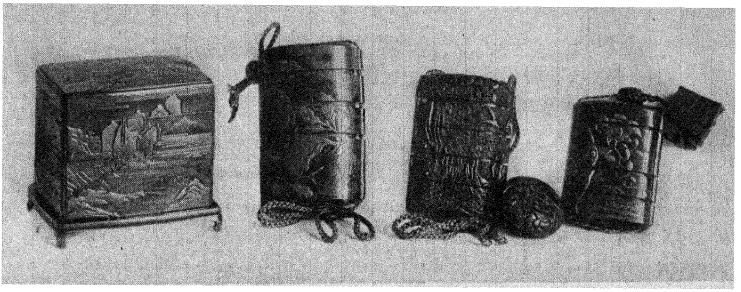


FIG. 75.—Gold and cinnabar lacquer, the work of Japanese artists. (*Courtesy of the Botanical Museum of Harvard University.*)

tion. Lacquer affords a remarkable protection as it is unchanged by acids, alkalies, alcohol, or heat up to 160°F. When pigments are used, they are mixed with the lacquer before drying.

The art of lacquering originated in China centuries before the beginning of the Christian era, and reached its highest development in that country during the Ming dynasty (1368–1644 A.D.). In Japan the first records go back to the fourth century, when lacquer was used for many purposes. The earliest specimens extant belong to the sixth century. The art reached its height during the seventeenth century, though much fine work was produced as late as the nineteenth century. The Japanese have outstripped their predecessors as regards the excellence of the products (Fig. 75) in all fields except the carving of lacquer. They have been especially skilled in the use of gold as a color. The process of lacquering is a very complicated and tedious one. In some cases from 300 to 400 coats are applied and the whole

operation requires several years for completion. The technique was kept a secret for many years.

Burmese lacquer is obtained from *Melanorrhoea usitata*. It dries more slowly than Japanese lacquer, but has been much used in recent years in an attempt to build up a native lacquer industry in Burma.

Natural lacquers are also obtained in Formosa and Indo-China. In the latter country *Rhus succedanea* is the source.

Shellac

Although not strictly a plant product, shellac deserves some consideration. It is prepared from stick-lac, a resinous substance secreted on the twigs of many trees by an insect, *Tachardia lacca*. The lac insect derives its food from the sap of the trees and secretes the resin as a sort of cocoon for the protection of itself and its young. Although some 90 species may serve as hosts for the insect, only seven are important, and these are often cultivated. They include *Butea monosperma, Schleichera oleosa, Zizyphus xylopyrus, Ficus religiosa, Acacia arabica, Cajanus Cajan,* and *Zizyphus Jujuba. Butea monosperma* was used as a host as early as 250 A.D. At first a valuable red dye which was obtained from the insect was the only desired product. Since 1590 A.D. the resinous excretions have been more important. Most of the shellac of commerce is prepared by native workers. India furnishes over 97 per cent of the total output, the remainder coming from Burma, Siam, and Indo-China. The crude stick-lac is soaked to extract the red dye and is then dried and powdered to a granular consistency. This seed-lac is melted and thin sheets of it are allowed to harden. These are broken up into the semitransparent, brittle, orange-red flakes which constitute shell-lac. If the melted seed-lac is poured out in drops, it hardens into the thick round pieces known as button-lac. Shellac is often bleached.

Shellac has many industrial uses. It can be molded readily and is the most satisfactory material for the manufacture of phonograph records. It is a high-grade insulator and is extensively used in the electrical industry. It is the principal spirit-varnish resin yielding a tough film with a smooth finish, which is capable of a high polish. Shellac varnishes cannot be used for outside work for they are not water resistant. Shellac is also

used in making sealing wax, drawing inks, some water colors, and nitrocellulose lacquers; for sizing papers; for stiffening felt hats; and, in India, for numerous ornamental purposes.

Acaroid Resins

The acaroid or grass-tree resins are obtained from Australian trees belonging to the genus *Xanthorrhoea*. These plants are among the few monocotyledons, other than palms, which have an arboreal habit. They consist of a short woody stem, composed of the old leaf bases, surmounted by a tuft of long rushlike leaves. The resin collects around the bases of the old leaves and is removed by beating the stem. The yellow acaroid resins reach the market in the form of elongated or round reddish-brown pieces. They are obtained chiefly from *Xanthorrhoea hastilis*. Red acaroid resins from *X. australis* and allied species are much more common. They consist of uneven pieces of a brownish color. The acaroid resins are used in making sealing wax, gold size, and spirit varnishes for use in coating metals; as a substitute for rosin in paper sizing; as a mahogany stain; as a source of picric acid; and in medicine.

Sandarac

Sandarac is a soft pale-yellow resin obtained chiefly from *Callitris quadrivalis* (or *Tetraclinis articulata*, as it should be called), a small tree of Northern Africa. Australian species of *Callitris* are also a source of sandarac. The resin is formed between the inner and outer layers of the bark and is excreted in the form of small tears, which quickly become opaque. Sandarac yields a hard, white, rather brittle spirit varnish, especially useful for coating labels, negatives, cardboard, leather, and metals. It was formerly used in medicine and was well known to the older civilizations.

Mastic

Mastic is a very old resin and was known as early as 79 A.D. The most useful variety is Chios mastic, derived from *Pistacia lentiscus*, a small tree of the Mediterranean region. Although the resin exudes naturally, the flow is aided by removing strips of bark. Some of the resin adheres to the trunk in the form of long, ovoid, pale-yellow, brittle tears, while the remainder falls

to the ground. Bombay mastic, which consists of large irregular pieces of a dull, milky color, comes from *P. cabulica*. Mastic yields a pale varnish used for coating metals and pictures, both oils and watercolors. It is also used in lithographic work, in medicine, and as a cement for dental work. It is one of the most expensive and high-grade resins.

Dragon's Blood

Dragon's blood includes various red substances of a resinous nature. Sumatra dragon's blood is obtained from *Daemonorops Draco*, a climbing rattan palm of Eastern Asia. The dark reddish-brown resin occurs as small granules on the scaly fruits. It is used in the manufacture of red spirit varnishes for metals and in dental work. During the eighteenth century the great Italian violin makers used dragon's blood in their varnishes. Socotra dragon's blood, a resin that exudes from the stem of *Dracaena cinnabari* of Western Asia, is also used to some extent for varnishes, dyes, and stains. Dragon's blood is sometimes obtained from tropical American species of *Dracaena* and other Asiatic species of *Daemonorops*.

Kinos

Kinos, or gum kinos as they are usually called, are derived from several sources. Malabar kino consists of the dried juice of *Pterocarpus Marsupium*, a large Indian tree. The trees are tapped and the juice is boiled down. It reaches the market in the form of small, brownish-red, brittle pieces. West African kino is a red resin from *P. erinaceus*. Bengal kino comes from *Butea monosperma*. Several Australian species of *Eucalyptus* are important sources of gum kino. The principal species is the red gum (*Eucalyptus rostrata*). The kino is secreted in cavities between the wood and bark, and oozes out after incisions have been made. In the air the resin hardens into a solid reddish mass. Several tropical American trees, chiefly *Dipteryx odorata* and *Coccoloba uvifera*, also yield kinos. Kinos find their chief use in medicine for throat troubles, and are used to some extent in tanning.

OLEORESINS

The oleoresins contain a considerable amount of essential oils in addition to the resinous materials, and consequently they are

more or less liquid in nature. They have a distinct aroma and flavor. Among the oleoresins are included the turpentines, balsams, and elemis. The distinctions between these groups are very slight and there is often a confusion of terms.

Turpentines

Turpentines are oleoresins obtained almost exclusively from coniferous trees. They are viscous, honeylike liquids or soft and brittle solids. The resin is secreted and stored in ducts near the cambium layer and exudes naturally as a soft, sticky substance, often called pitch. For commercial use crude turpentine is obtained by tapping the trees. On distillation turpentines yield the essential oil or spirits of turpentine, and rosin, both of which are exceedingly useful products, around which an important industry has been built up. This turpentine or naval-stores industry is one of the oldest of the forest industries. The Trojans and Greeks were familiar with pitch and its uses. Today the industry is valued at $40,000,000 annually. The United States leads in production. Turpentine and rosin, however, are produced in many European countries, and even in India and Indo-China

The Turpentine Industry in the United States

The history of the turpentine industry in the United States is closely identified with the economic development of the South. Tar and pitch were among the earliest exports of the country, and the industry was practically the only source of livelihood in the early days of the Carolinas. At first the products were used chiefly in connection with sailing vessels, a fact that gave the name "naval stores" to the industry. This name still holds, although today turpentine and rosin are the products.

The most important source of the crude turpentine used in the naval-stores industry is the longleaf pine (*Pinus palustris*). This species (Fig. 76) furnishes 90 per cent of the raw material. The Cuban or slash pine (*P. caribaea*) is used to some extent, and attempts are being made to develop the western yellow pine (*P. ponderosa*). The industry is carried on chiefly in the eight coastal states from North Carolina to Texas, with Florida the present center of production. The industry is waning at the present time, owing partly to the depletion of the virgin timber

supply and partly to the lack of demand for the products. Attempts are being made to conserve the supply by reforestation and better methods of tapping. In the best year, 1900, over 38,000,000 gal. of turpentine and 4,300,000 bbl. of rosin were produced. Normally about half the product is exported, chiefly to Europe.



FIG. 76.—A virgin stand of longleaf pine (*Pinus palustris*). This species is the chief source of turpentine and rosin. (*Photo by U.S. Forest Service.*)

Turpentine oozes out from the resin canals after the cambium layer has been exposed by a cut, and at the same time the development of new ducts above the cut is stimulated. In the species used commercially the ducts are exceedingly large, and there is a correspondingly heavy production of the oleoresin. The first woods operation in the turpentine industry is known as boxing. This is carried on in winter and consists of cutting a cavity near the base of the tree 3 to 4 in. wide, 6 or 7 in. deep, and 1 ft. long. From one to four of these boxes are cut on each tree. The next stage is cornering, which enables the resin to flow into the box more freely. Chipping, the reexposing of the cambium, has to

be performed every week; otherwise the oxidation and crystallization of the resin would clog the old ducts. Every three weeks the resin is removed from the boxes (Fig. 77) and carried to the distillery. At the end of each season the resin that has adhered to the face of the cut and never reached the box is scraped off. This contains many impurities and yields an inferior grade of turpentine and rosin. The recent introduction of a cup and gutter system of tapping the trees is productive of a greater



FIG. 77.—Collecting the resin from a longleaf pine which has been tapped by the cup-and-gutter method.

yield and is much less wasteful. There is also much less injury to the tree.

The distillation of the turpentine is carried on in copper stills (Fig. 78), the process lasting from 2 to 3 hours. The distillate is collected in barrels, where the *oil of turpentine* rises to the top and is run off for storage. The residue, which is *rosin*, while still hot, is run through a series of screens to remove any impurities, and then into a cooling vat. When cool, it is transferred to slack barrels where it completely hardens within 24 hours. Not all the turpentine is removed during distillation as this yields a better grade of rosin.

The production of an inferior grade of turpentine and rosin as the result of the destructive distillation of pine wood has already been discussed.

The oil of turpentine, which is usually referred to as "turpentine" or "spirits of turpentine," has many uses. It is of

major importance in the paint and varnish industry, where it has a thinning action, due to its properties as a solvent. It is used in connection with the printing of cloth, particularly cotton and woolen; as a solvent for rubber and gutta-percha; in medicine; and in the manufacture of many chemicals.

Rosin or colophony is even more important in industry. It is used in the manufacture of soap, varnishes, paints, oilcloth, linoleum, sealing wax, printer's ink, roofing and floor coverings, and various chemicals. It serves as the chief sizing material for paper, and constitutes the brewer's pitch used for lining beer

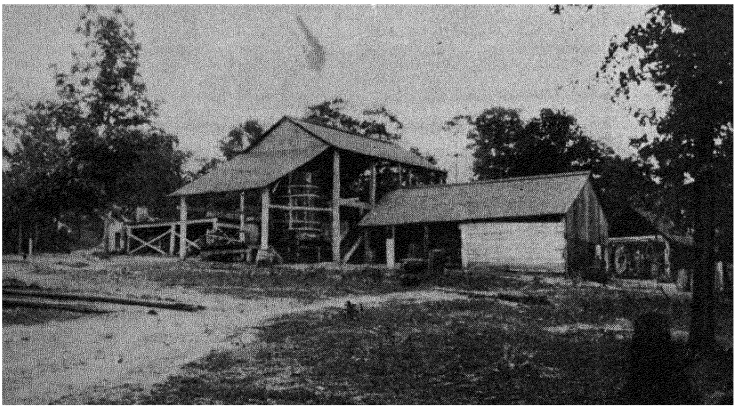


FIG. 78.—A turpentine distillery. The crude resin yields oil of turpentine and rosin as products.

barrels. Rosin oils are utilized as greases, lubricants, and solvents.

The Turpentine Industry in Foreign Countries

The naval-stores industry is highly developed in France, where *Pinus Pinaster*, known in that country as the maritime pine (*P. maritima*), is cultivated and tapped for its turpentine. The products are of the highest quality and are preferred to those produced in the United States. Spain is the third largest producer of naval stores and is becoming of increasing importance. Four species of pine are tapped, *P. Pinaster*, *P. halapensis*, *P. nigra*, and *P. Pinea*. Most of the forests are under government

control. In Portugal the industry is just becoming prominent and vast areas are as yet untouched. *P. Pinaster* and *P. Pinea* are the sources. Greece is also increasing in importance as a producer of naval stores, utilizing *P. halapensis*. In Russia, Poland, and Germany inferior grades of rosin and turpentine are obtained from *P. sylvestris*.

The turpentine industry is now being developed in many parts of Asia, particularly Indo-China, the Dutch East Indies, and India. In India several species of pine are available, and also the only non-coniferous tree that is a source of turpentine and rosin. This is the Indian frankincense (*Boswellia serrata*). The great distances and lack of transportation facilities have handicapped the industry in India, but in spite of all obstacles it continues to expand The British government is much interested in fostering the industry, for India is practically the only part of the empire where naval stores can be produced.

Turpentines of Minor Importance

Crude turpentines from various species of conifers are often used in their natural state for purposes other than the production of naval stores. Some of them have been important in industry, in the arts, and especially in medicine for over four centuries. Among the best known may be mentioned:—

Canada Balsam.—This oleoresin is a true turpentine, rather than a balsam, as the name would indicate. It is secreted by the balsam fir (*Abies balsamea*) of the northern United States and Canada. The resin collects in elongated blisters on the bark and only small amounts are obtainable. It is estimated that a tree will yield from 8 to 10 oz. a year. Collectors use a pot with a spout cut at an angle. This is forced into the blisters and held in place while the balsam drains out. The balsam is a viscid yellowish or greenish substance. Its chief use is as a mounting medium for microscopic work and as a cement for optical lenses. It is very transparent and has a high refractive index, which results in a minimum dispersal of light. The medicinal value of Canada balsam was recognized as early as 1607. It is used as an irritant, stimulant, and antiseptic, and is a component of collodion and many plasters.

Oregon balsam, obtained from the Douglas fir, has similar properties and uses.

Spruce Gum.—Spruce gum is the natural exudation of the various spruces of the northern United States and Canada, with *Picea rubens* the chief source. The thin, clear, bitter, sticky oleoresin is secreted in blisterlike cavities (Fig. 79) in the bark or in longitudinal fissures in the wood. It hardens on exposure to the air and is collected when hard or semisoft. About 500,000 lb. are used each year as a masticatory. The gum softens in the



FIG. 79.—A red spruce (*Picea rubens*) in Maine, showing the spruce gum oozing from fissures in the bark. (*Photo by V. C. Isola; courtesy of S. J. Record.*)

mouth and assumes a reddish color. It has a pleasing resinous taste.

Venetian Turpentine.—Venetian turpentine is obtained from the European larch (*Larix decidua*), a common tree in the mountains of Central Europe. Unlike all other conifers, the resin ducts are located in the heart of the tree so that holes must be bored in order to obtain the resin. The trees are tapped in the spring. Venetian turpentine has been an important product since the middle of the eighteenth century. It is a yellowish or greenish liquid with a characteristic odor and taste. It is used in varnishes, histology, lithographic work, and veterinary medicine.

Other crude turpentines of less importance include Bordeaux turpentine from *Pinus Pinaster*, Strasbourg turpentine from *Abies alba*, and Jura turpentine from *Picea Abies*. In the case of the first two of these European turpentines, the crude exudation is used to some extent, but more often it is strained and

filtered through cloth. The residue, known as Burgundy pitch, is a stimulant and counterirritant, and is used in plasters, ointments, and other pharmaceutical preparations.

Balsams

Technically balsams are oleoresins that contain benzoic or cinnamic acid and so are highly aromatic. The term "balsam," however, is often applied erroneously to quite different substances, such as Canada balsam, copaiba balsam, etc. The true balsams contain much less oil than the turpentines and are more or less viscous substances. They yield essential oils on distillation. Balsams are used in medicine and as fixatives in the perfume industry.

Balsam of Peru

Balsam of Peru is obtained from *Myroxylon Pereirae,* a tall tree of Central America which is cultivated in many tropical and subtropical countries. The wood resembles mahogany and is quite valuable. The balsam is a dark, reddish-brown, thick, syrupy, viscous liquid, and is a pathological product formed as a result of wounding the tree. The trunks are beaten with a blunt instrument and the injured bark is then charred. It soon falls off naturally or is removed. The balsam exudes from the exposed surface of the wood and is collected on rags. These rags are later boiled to free the balsam, which is purified. Balsam of Peru is used in medicine for healing slow wounds and skin diseases. It is also used in the treatment of coughs, bronchitis, and similar ailments, because of its stimulative and antiseptic effect on the mucous membranes. It is utilized in perfumes as a fixative for the heavier odors and has served as a substitute for vanilla. Its common name is a misnomer, for the tree does not grow in Peru. The United States imports its supply chiefly from San Salvador.

Balsam of Tolu

Balsam of Tolu is a pathological product obtained from *Myroxylon Balsamum,* a tree of Venezuela, Colombia, and Peru. V-shaped incisions are made in the trunk and the balsam slowly exudes and is collected in gourds. It is a brown or yellowish-brown plastic substance with a pleasant aromatic taste and odor.

It is used for salves and ointments and as an expectorant and antiseptic in the treatment of coughs, colds, and bronchitis. It is sometimes used to flavor cough syrups. Considerable amounts are used as fixatives in the perfume industry.

Styrax

Two varieties of styrax or storax enter into commerce. The most important type, which is the styrax of antiquity, is known as *Levant styrax*. This is obtained from *Liquidambar orientalis*, a small tree common along the coasts of southwestern Asia Minor. The balsam is a pathological product formed as a result of wound stimulation. The outer bark is bruised and soon the balsam exudes into the inner bark. The outer layers are discarded and the balsam is recovered by boiling the inner layers in sea water. The residual bark is dried and used for fumigating. Styrax is a semiliquid, grayish-brown, sticky, opaque substance with a pronounced aromatic odor. It is used in soaps and cosmetics, as a fixative for the heavy "oriental" type of perfume, in lacquers and incense, as a flavoring for tobacco, and in medicine as a stimulant to the mucous membranes and for the treatment of scabies.

American styrax is obtained from the sweet gum (*Liquidambar Styraciflua*). Although this tree ranges from New England to Mexico and Central America, the commercial supply of styrax comes only from Guatemala, Honduras, and Venezuela. This balsam is a thick, clear, brownish-yellow, semisolid or solid substance and has the same uses as the Levant styrax.

Benzoin

Benzoin is a solid balsam and is often classed as a resin or balsamic resin. It is a pathological product obtained from various species of *Styrax*, found in Southeastern Asia and the East Indies. The balsam oozes out from incisions made in the trunk and branches. Two varieties are known in commerce. *Siam benzoin* comes from *Styrax tonkinense* and *S. benzoides* and occurs as yellowish or brownish pebblelike tears with a milky white center. The tears are hard and brittle at ordinary temperatures and occur separately or adhere together only slightly. *Sumatra benzoin*, from *Styrax Benzoin*, occurs in reddish or grayish-brown blocks or lumps, composed of masses of tears stuck together.

Benzoin is exceedingly aromatic with a vanillalike odor. It is used in medicine as a stimulant and expectorant; and in the preparation of heavy sweet perfumes, soap, toilet waters, lotions, tooth powders, incense, and fumigating materials.

Other Oleoresins

There are numerous oleoresins that do not belong to either the turpentines or balsams. Among the more important may be mentioned copaiba, elemi, and Mecca balsam.

Copaiba

Copaiba, known also as copaiba balsam or copaiva, is a natural oleoresin obtained from several species of *Copaifera* native to tropical South America. The copaiba trees are small (Fig. 80) with strong, tough, durable wood, which contains resin ducts of large size. So much oleoresin is secreted and stored in cavities that sometimes the pressure causes the trunk to burst open. Copaiba is obtained by boring holes into the heartwood. The secretion flows out very rapidly. It is a thin, clear, colorless liquid at first, but turns yellow and becomes more viscid with age. Several commercial varieties occur, which differ in the amount of resins and essential oils present as well as in the source. The most important of these are Maracaibo copaiba from Venezuela, obtained from *Copaifera officinalis*, which contains considerable resin and is rather thick; and Para copaiba, a very fluid grade from Brazil, obtained from *C. Langsdorfii*. Copaiba is used in making varnishes, lacquers, and tracing paper. In medicine it is used as a disinfectant, laxative, diuretic, and mild stimulant.

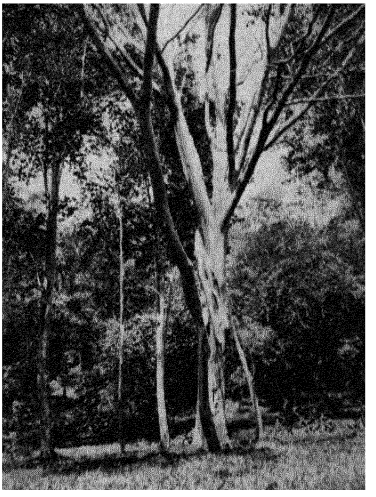


Fig. 80.—*Copaiba officinalis*, a source of copaiba balsam. (*Photo by C. D. Mell; courtesy of S. J. Record.*)

There are many substitutes for copaiba, chief among which are gurjun balsam and illurin balsam.

Gurjun balsam is obtained from *Dipterocarpus turbinatus* and related species of India and the East Indies. The thick, opaque, grayish oleoresin is obtained by cutting holes in the trunk.

Illurin balsam, a very fragrant oleoresin with a thick, pungent, pepperlike odor, comes from a West African tree, *Daniella thurifera.* This species, sometimes known as Sierra Leone frankincense, is characteristic of the drier open forests and savannahs of Upper Guinea. The resin exudes in a copious flow from the base of the trees. A similar product comes from *D. Oliveri,* a species of the denser moist forests. This oleoresin, under the name of wood oil, is one of the chief products of Nigeria.

Elemi

The term "elemi" is used as a collective name for several oleoresins of different origin; it is also used erroneously as a synonym for some of the softer copals. Elemis differ considerably in their characteristics. These oleoresins exude as clear pale liquids, but they tend to harden on exposure. Some remain soft, while others become quite hard.

Manila elemi is the most important and the best known of the elemis. Its source is the pili tree (*Canarium luzonicum*) of the Philippine Islands. The oleoresin is secreted in the bark and oozes from the trunk in fragrant white masses. The natives use elemi for torches and for caulking their boats. Manila elemi is used in lithographic work and the manufacture of inks, in the varnish industry to give toughness and elasticity to the products, in perfumes, and in medicine in plasters and ointments.

Less important varieties include African elemi from *Boswellia Frereana;* American elemi from *Amyris elemifera, A. balsamifera,* and related species; and Brazilian elemi from *Protium heptaphyllum.*

Mecca Balsam

Mecca balsam is a greenish turbid oleoresin with an odor of rosemary. It is obtained from *Commiphora Opobalsamum,* an Arabian species. This material has long been used in incense and for perfumes of an oriental type. It has some medicinal

material since Biblical times. It is still an indispensable ingredient of incense for religious observances, and is also used in perfumes, pastilles, and fumigating powders.

Opopanax and Bdellium

These gum resins are much less important. **Opopanax** is derived from two very distinct plants, *Commiphora Kataf* of the *Burseraceae* and *Opopanax Chironium* of the *Umbelliferae*. It is used in perfumery and was formerly of importance in medicine.

Bdellium is a bitter aromatic gum resin obtained from *Commiphora Mukul* of India and *C. africana* of Africa. It is used to some extent in perfumery.

OTHER RESINS

Several other resinous substances, which find no use in industry, will be considered with the medicinal plants. These include aloes, guaiacum, jalap, podophyllum, and scammony. Gamboge, a gum resin, has already been discussed under dye plants.

1935 IMPORTS OF GUMS AND RESINS

	Pounds		Pounds
Amber	284	Kauri	1,386,821
Asafetida	55,572	Lac	7,483,575
Balsam of Peru	71,312	Mastic	20,857
Balsam of Tolu	56,070	Myrrh	47,862
Benzoin	96,697	Rosin	1,225,989
Burgundy pitch	24,443	Sandarac	121,365
Canada balsam	7,872	Shellac	20,054,452
Copaiba balsam	187,914	Styrax	67,244
Copals	20,447,942	Tragasol	2,129,179
Damars	15,004,904	Turpentine spirits, gal	625,188
Dragon's blood	53,912	Venetian turpentine and other crude turpentines	38,404
Gum arabic	7,954,840	Other resins	1,638,743
Gum tragacanth	2,473,524		
Kadaya gum	4,829,884		

CHAPTER VIII

ESSENTIAL OILS

The essential oils, or volatile oils as they are often called, are found in many different species of plants. These oils are distinguished from fatty oils by the fact that they evaporate or volatilize in contact with the air and possess a pleasant taste and strong aromatic odor. They can be readily removed from plant tissues without any change in composition. Essential oils are very complex in their chemical nature. The two principal groups are the terpenes, which are hydrocarbons, and the oxygenated and sulphuretted oils.

The physiological significance of these oils as far as the plant is concerned is not obvious. They probably represent by-products of metabolism rather than foods. The characteristic flavor and aroma that they impart are probably of advantage in attracting insects and other animals which play a role in pollination or the dispersal of the fruits and seeds. When present in high concentration, these same odors may serve to repel enemies. The oils may also have some antiseptic value.

All distinctly aromatic plants contain essential oils. They occur in some 60 families and are particularly characteristic of the *Lauraceae*, *Myrtaceae*, *Umbelliferae*, *Labiatae*, and *Compositae* The oils are secreted in internal glands or in hairlike structures. In some instances, as in wintergreen and mustard, the oil is not present in the plant, but develops only as the result of chemical action when the ground-up plant tissue is extracted with water. Almost any organ of a plant may be the source of the oil: flowers (rose), fruits (orange), leaves (mint), bark (cinnamon), root (ginger), wood (cedar), or seeds (cardamom).

Essential oils are extracted from the plant tissues in various ways depending on the quantity and stability of the compound. The usual method is by steam *distillation* (Fig. 81). Ground material is allowed to stand in water in a copper still and is then heated to the boiling point. The oil vaporizes and, together

with the steam, passes into a condenser. On cooling, the oil collects on the surface of the water and is removed and filtered. In cases where heat would destroy the odors, *expression* is resorted to; with flowers, which have a very delicate odor, an *extraction* process is used. The oil may be extracted by means of volatile solvents or by maceration with a fat. When solvents are used, the most highly concentrated perfumes are obtained. The maceration process is known as *enfleurage*. Some flowers, like rose, violet, and orange, are treated with a warm fat (*enfleu-*

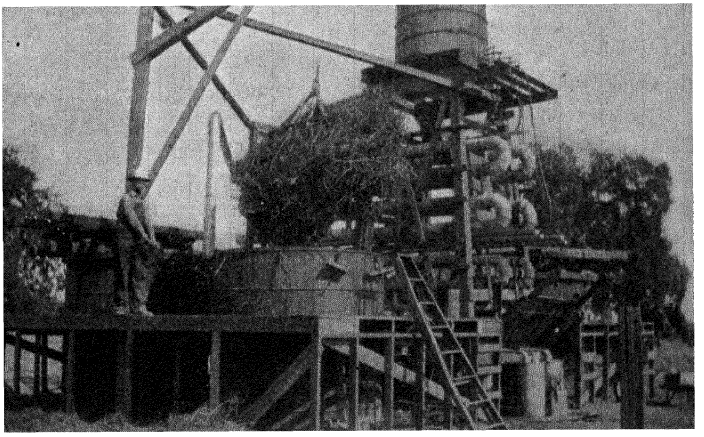


FIG. 81.—A Japanese mint-oil still in Colorado.

rage á chaud), while other flowers with an extremely subtle fragrance are macerated with a cold fat (*enfleurage á froid*). Glass plates are coated with the fat. The flowers are placed on this and allowed to remain for several days. Eventually the fat absorbs all the oil. The pomade, as it is then called, is treated with alcohol to dissolve out the oil.

Essential oils have very varied industrial applications. Because of their odor and high volatility they are extensively used in the manufacture of perfumes, sachets, soap, and other toilet preparations. Many are used as flavoring materials or essences for candy and ice cream and in cooking, and for cordials, liqueurs, and nonalcoholic beverages as well. Still others have therapeutic, antiseptic, or bactericidal properties and so are valuable in medicine and dentistry. In fact, nearly all the

essential oils have been used at some time in some country for medical purposes, although comparatively few are official at the present time. Some of the oils are used as clearing agents in histological work; as solvents in the paint and varnish industries; as insecticides and deodorants; in the manufacture of various synthetic odors and flavors; and in such widely diversified products as chewing gum, tobacco, shoe polish, library paste, printer's ink, tooth paste, and fish glue.

Although an enormous quantity of volatile oils is utilized in our industries, the growing and distillation of oil-producing plants are practiced only to a slight extent in the United States. This country leads in the cultivation of peppermint and spearmint and in the production of the oils. Wormwood, wormseed, tansy, and dill are also grown commercially to some extent. Recent cultural experiments with lavender and geranium seem to indicate that the commercial production of various perfume oils in the United States is at least possible. A few oils are extracted from native wild plants. These include the oils of turpentine, sassafras, wintergreen, sweet birch, witch hazel, eucalyptus, and pennyroyal. In other cases oils are obtained as by-products of various industries. Among such are lemon, orange, apricot, bitter almond, cedarwood, and hop oils. Most of the essential oils used in the United States, however, are imported.

Any economic classification of essential oil plants is exceedingly difficult, for the various groups intergrade. For example, clove oil, obtained from the familiar spice, is used for flavoring, in perfumery, in medicine, in histology, and as a source of synthetic vanilla. In numerous cases the same oil is used for flavoring and in medicine. Our discussion of spices and other food adjuncts, of flavoring materials, and of medicinal plants will be reserved until later. At the present time we are concerned only with those oil-yielding plants which are used for perfumery and similar purposes or which have other strictly industrial applications.

PERFUMES

It has often been said, as in the case of many other economic plant products, that the history of perfumes is the history of civilization. Certainly perfumes have been in vogue since the earliest recorded times. We know that the Egyptians and

ancient Hebrews used them for both personal and religious purposes. They played an important part in the life of the Romans and Greeks, reaching such a high degree of specialization in the case of the latter people that a special perfume was required for each part of the body. Later on we find that Catherine de' Medici knew as much about perfumes as she did about poisons, that in the time of Queen Elizabeth a gift of rare perfumes was a sure way to win the royal favor, while the court of Louis XIV at Versailles had a particular perfume for each day in the year, the preparation of which was superintended by the king himself. In those days perfumes were of considerable hygienic, as well as aesthetic, value, for they acted as true antiseptics and deodorants and masked offensive odors at a time when personal cleanliness was too often overlooked. Today perfumes are still in great demand. The consumption of the natural products is increasing in spite of the many synthetic substitutes that the chemist has put on the market. These latter materials are not so lasting as those obtained directly from the plants. They are used for cheap grades, to fortify the natural products, and for blends. The most valuable perfumes are combinations of several essential oils. Frangipani, for example, contains sandalwood, sage, neroli, orris root, and musk, while one of the formulas for Eau de Cologne, dating from 1709, calls for neroli, rosemary, lemon, and bergamot dissolved in pure alcohol and aged. The expert perfumer must be able to blend the several oils at his command as an orchestra leader combines the various instruments into a perfect whole.

In addition to the aromatic oils, the finer perfumes contain fixatives—substances which are less volatile than the oils and which delay evaporation. These are chiefly of animal origin and include musk, ambergris, and civet. Benzoin and other balsams and various fatty oils are also used for this purpose.

Most of the natural perfumes are made in southern France, the industry centering around Grasse and Cannes in the French Riviera. In this area garden flowers are cultivated on a large scale, and from 10,000,000,000 to 12,000,000,000 lb. of flowers are gathered annually. These include 5,500,000 lb. of orange blossoms, 4,400,000 lb. of roses, 440,000 lb. of jasmine, and 330,000 lb. of violets. Large quantities of cassie, tuberoses,

jonquils, thyme, lavender, rosemary, and geraniums are grown, and many other fragrant species to a lesser degree. Flowers are also grown for the perfume industry to some extent in England, Reunion, North Africa, and various European and Asiatic countries.

Perfume Oils

Some of the more important essential oils used for perfumes will be considered at this time.



FIG. 82.—The damask rose (*Rosa damascena*). The flowers of this plant are the source of otto of roses, one of the most expensive of perfumes. (*Photo by E. H. Wilson; courtesy of the Arnold Arboretum.*)

Otto of Roses.—This valuable oil, sometimes called attar or ottar of roses, has long been known and is still one of the favorite perfumes, either alone or in combination. Bulgaria supplies most of the commercial supply at the present time, utilizing the flowers of the damask rose (*Rosa damascena*) (Fig. 82). Over 12,000 acres on the southern slopes of the Balkans are devoted to the cultivation of this small shrub. The harvest period covers about three weeks during May and June. The flowers are picked

in the early morning just as they are opening and are distilled as soon as possible. Until recently the peasant cultivators have utilized their own primitive stills, but now large modern distilleries are in operation. The oil is colorless at first, but gradually turns a yellowish or greenish color. About 20,000 lb. of the flowers are required to make 1 lb. of the essence, which is worth about $200. Very little pure otto reaches the markets, for it is almost always adulterated with geranium or palmarosa oil



FIG. 83.—Rose geraniums (*Pelargonium odoratissimum*) under experimental cultivation in Wisconsin.

or geraniol, all of which have a roselike odor. Otto of roses is also manufactured in France, Asia Minor, and India. In France the cabbage rose (*Rosa centifolia*) is used, and the perfume is obtained by both hot and cold enfleurage, as well as by distillation. Large quantities of rose water are also made. This consists for the most part of the water left after distillation, which still contains some otto. It is sometimes prepared by dissolving a small amount of otto in water.

Geranium.—The leaves of several species of *Pelargonium* yield an essential oil on distillation. Geranium oil finds its chief use as an adulterant of, or substitute for, otto of roses in making perfumes and soap. *P. graveolens*, the species most frequently cultivated in Europe, chiefly in southern France and Spain, is also grown in Algeria and Reunion. In recent years cultural experiments have been carried on in Florida, Texas, and Cali-

fornia with *P. odoratissimum* (Fig. 83), the rose geranium. The plants are easy to propagate from slips and are productive for five or six years after reaching maturity. They can be grown only where there is freedom from freezing temperatures. A good

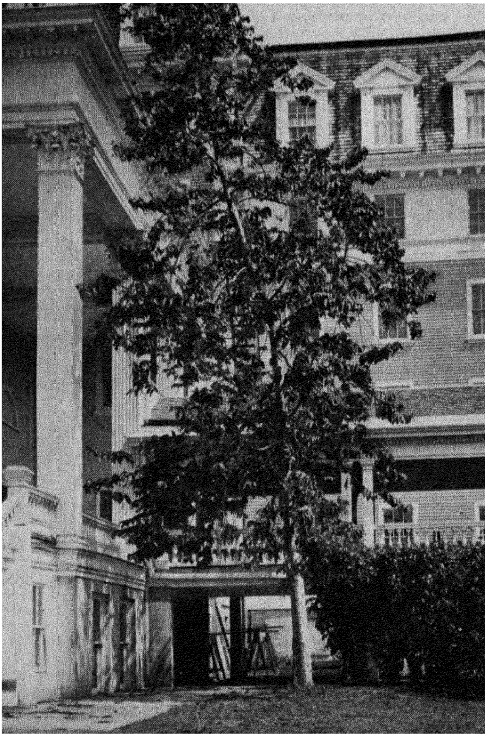


FIG. 84.—The ylang-ylang (*Canangium odoratum*). The flowers of this Asiatic species yield one of the most important essential oils used in the perfume industry. A few specimens of this tree, one of which is pictured here, are to be found in Florida.

grade of oil is obtained from the leaves, and the plant may prove a desirable addition to the essential-oil plants that are cultivated in the United States.

Ylang-ylang.—This is one of the most valuable and important oils in the perfumer's art, and is present in almost every perfume. The name means "flower of flowers." The ylang-ylang tree (Fig. 84) is an Eastern Asiatic species, *Canangium odoratum*. Its yellowish-green bell-shaped flowers have an exceedingly delicate

and evanescent fragrance. The oil, often known as cananga oil, is derived by simple distillation from the petals of fully opened blossoms. The Philippine Islands are the chief producers of ylang-ylang, although the tree grows wild and is also cultivated in various parts of Southern Asia and the East Indies. Long known to the native peoples of the East, this oil first reached Europe about 1864. Since that time it has been in great demand even though it is rather expensive.

Cassie.—The flowers of *Acacia Farnesiana* yield an essential oil almost as valuable as ylang-ylang or otto of roses. The plant is a native shrub of the West Indies, but it occurs today in many tropical and subtropical countries. It is extensively cultivated in southern France, Algeria, and India as a source of perfume. The oil is removed from the petals by maceration with cocoa butter or coconut oil. It has an odor like violets, and is much used for pomades, sachets, and powders.

Neroli.—Oil of neroli, which is extensively used in blends and for mixing with synthetic perfumes, is obtained from orange blossoms. True oil of neroli, or *neroli bigarade*, is distilled from the flowers of the bitter orange (*Citrus Aurantium*), while *neroli Portugal* comes from the sweet orange (*C sinensis*). Southern France leads in the production of neroli, although a considerable amount is made in the other Mediterranean countries and in the West Indies.

Oranges are the source of other essential oils used in perfumes. The leaves and twigs (and formerly the small immature fruits) supply *petitgrain* oil. Both bitter and sweet oranges are utilized and the oil is obtained by enfleurage or the use of solvents. *Oil of orange* is obtained by expressing the ripe peel. Neither of these oils is so valuable as neroli.

Bergamot.—This greenish oil is expressed from the rind of the bergamot (*Citrus Bergamia*). It has a soft sweet odor and is extensively used in the United States for scenting toilet soaps and in mixed perfumes. It is imported chiefly from Italy and Sicily.

Orris.—The rhizomes of *Iris florentina* and allied species contain an essential oil that has the odor of violets. A tincture of orris root is often used to adulterate pure extract of violets, while the powdered root is the basis of violet powder. The plant is cultivated in Southern Europe, Persia, and northern India.

The rhizomes are peeled and dried in the sun, and the odor gradually develops. Orris is used to some extent as a flavoring substance.

Calamus.—Calamus root is the sweet and aromatic rhizome of the sweet flag (*Acorus Calamus*), a common plant of marshy ground in Europe, Asia, and America. In a powdered form calamus is used for sachet and toilet powders, while the distilled oil is used in perfumery. It is also used for medicinal and flavor-

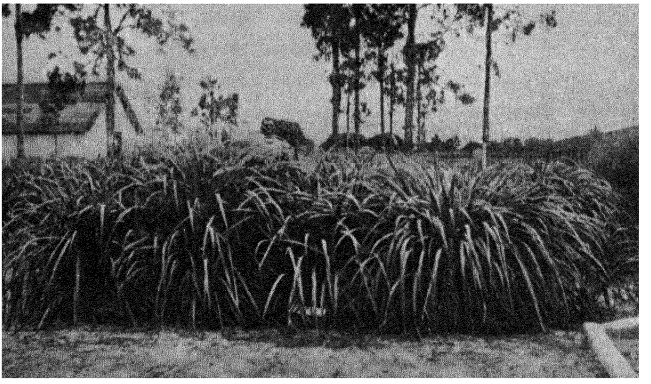


FIG. 85.—Citronella grass (*Cymbopogon Nardus*), the source of the familiar oil of citronella.

ing purposes. The candied root was at one time a popular confection.

Grass Oils.—The grass family is the source of several important essential oils which are extensively used in perfumery. The genus *Cymbopogon*, formerly included in *Andropogon*, is especially rich in perfume plants.

Oil of Citronella.—This widely dispersed commodity is distilled from the leaves of *Cymbopogon Nardus* (Fig. 85). Thousands of acres of citronella grass are cultivated in Java and Ceylon. The pale-yellow oil is inexpensive and is much used for cheap soaps and perfumes and as an insect repellent. The oil contains 80 to 90 per cent geraniol, and so is important as a substitute for otto of roses.

Lemon-grass Oil.—The leaves of *Cymbopogon citratus* yield on distillation a reddish-yellow oil with a strong odor and taste of

lemons. The plant is common everywhere in the tropics and is cultivated in India and Ceylon. The oil is much used in perfumery and in toilet soaps and as a source of ionone, from which synthetic violet is made. Lemon-grass oil is also extensively used in medicine and as a flavoring substance.

Palmarosa and Ginger-grass Oils.—These nearly identical oils are much used as adulterants of otto of roses, as they contain a large amount of geraniol. *Cymbopogon Martinii* and a variety are cultivated in India as a source of these oils, which are exported in large quantities.

Oil of Vetiver.—This oil is obtained from the roots and rhizomes of the khuskhus plant (*Vetiveria zizanioides*), a native of India and Bengal, but now grown throughout the tropics and subtropics. The roots are very sweet scented and are made up into mats, fans, screens, awnings, sunshades, baskets, sachet bags, and pillows. The plant has been introduced into the West Indies and Louisiana, where every French garden has some. It readily escapes from cultivation and has become naturalized in many places. On distillation the roots yield an oil much like citronella which is used for high-grade perfumes and in medicine. The leaves are odorless.

Oil of Bay.—The leaves of *Pimenta acris* on distillation yield this oil, which is used in perfumery and in the preparation of bay rum. The plant is a native of the West Indies, and the bay-rum industry is located in that region. Formerly the leaves were distilled in rum and water, but now the oil is dissolved in alcohol, with which are mixed various aromatic materials.

Lavender.—Lavender is a very old perfume and was used by the Romans in their baths. It is still one of the most important scents. The *true lavender* plant (*Lavandula officinalis*) is a native of Southern Europe, occurring on dry, barren soil. It is a low shrub (Fig. 86) with terminal spikes of very fragrant bluish flowers. Many horticultural forms and hybrids occur. Lavender is grown in southern France at altitudes varying from 1500 to 1800 ft., and large amounts are raised in England. Lavender has a clean odor and the dried flowers are used in sachets and for scenting chests and drawers. The oil is an important constituent of Eau de Cologne and is also used in medicine as a mild stimulant. Lavender water, a mixture of the oil in water and alcohol, is a highly popular toilet article in England.

Spike Lavender.—This plant (*Lavandula latifolia*) is coarser and yields an inferior grade of oil. It can be grown at lower altitudes than true lavender and is extensively cultivated in France and Spain. It is used in perfumes and cosmetics and to flavor the meat jellies known as aspic.

Violet.—Violet is one of the most popular perfumes and has a sweet and delicate odor. Blue and purple double varieties of *Viola odorata*, a native European species, are grown chiefly in



FIG. 86.—A field of lavender (*Lavandula officinalis*).

the vicinity of Nice. The oil is extracted by solvents or maceration with hot fats. Real violet perfume today is rare and expensive, for it has been almost entirely replaced by synthetic products derived from ionone.

Jasmine.—Jasmine is one of the most highly esteemed of perfumes and the plant is extensively cultivated in southern France. The species used is *Jasminum grandiflorum*, which is usually grafted on a less desirable variety. The flowers are picked as soon as they are open and the oil is extracted by enfleurage.

Carnation.—There are over 2000 horticultural varieties of carnation, all derived from *Dianthus Caryophyllus*, a species of Southern Europe, Northern Africa, and tropical Asia. Forms

with the most desirable form, size, and color have the least odor. Less highly cultivated strains have the richest odor and are used for the perfume. The oil is extracted by enfleurage and by solvents. Most of the present-day supply is synthetic.

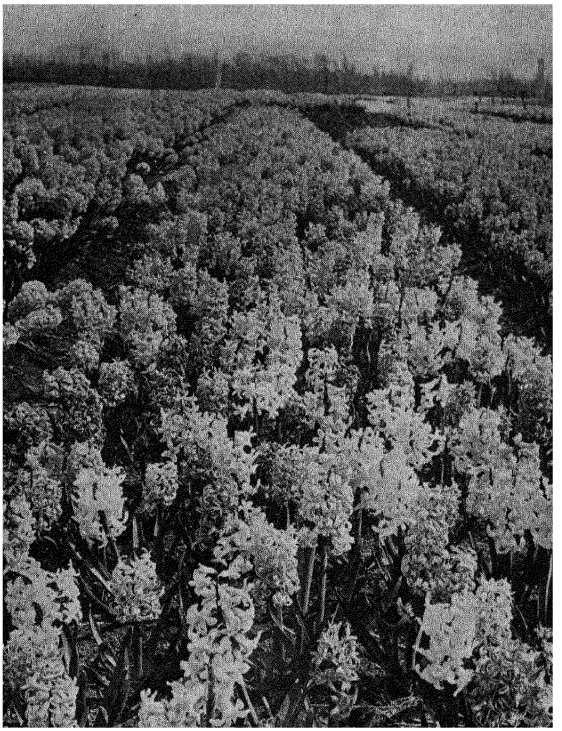


FIG. 87.—A field of hyacinths (*Hyacinthus orientalis*). These familiar ornamental plants are extensively grown in France for making perfume.

Rosemary.—The rosemary (*Rosmarinus officinalis*), a native of the Mediterranean region, has long been a favorite sweet-scented plant and has played an important role in the folklore of many countries. The plant is a small evergreen shrub and is cultivated in Europe and the United States. The oil is obtained by distillation of fresh flowering tops. It is used in Eau de Cologne, toilet soap, and medicine.

Hyacinth.—This plant (*Hyacinthus orientalis*) is a native of Western Asia and Asia Minor. It was introduced into Europe

during the sixteenth century and was grown as an ornamental plant, particularly in Holland. It is a familiar species in the United States (Fig. 87). Hyacinths are grown for perfume in southern France. The odor is heavy, sweet, and somewhat overpowering. Solvents are used to obtain the oil.

Oak Moss.—Oak moss or *mousse de chêne* is a recent and extremely valuable addition to the raw materials of the perfume industry. It comprises various lichens that grow on the bark of trees. The principal species are *Ramelina calicaris*, *Evernia furfuracea*, and *E. prunastri*. These lichens contain oleoresinous substances which are extracted by means of solvents. They not only have a heavy penetrating odor, but have a high fixative value as well.

Linaloe.—Mexican linaloe or lignaloe oil, which is used in perfumery to a considerable extent, is distilled from chips of the wood of two Mexican species, *Bursera Delpechianum* and *B. Aloexylon*. Cayenne linaloe or bois de rose oil is derived from *Aniba panurensis* of Guiana.

Sandalwood.—Sandalwood oil is obtained by distillation from the wood of *Santalum album* and allied species. The sandalwood tree grows wild in India and other parts of Southeastern Asia and is cultivated in many other countries. The oil is used throughout the Orient as a perfume and also in medicine. The sweet-scented wood is utilized for chests and boxes. The demand for sandalwood has been so great that in many parts of the East the true sandalwood has been practically exterminated. This has been brought about largely by careless methods of lumbering. There are numerous substitutes used in various parts of the world.

Patchouli.—Patchouli is obtained from the fleshy leaves and young buds of *Pogostemon Cablin*. The plant is a small shrub that grows wild in Southeastern Asia and is cultivated in China. The leaves are fermented in heaps and are then distilled. The dark-brown oil has a powerful odor, resembling that of sandalwood. It is used in perfumes, soaps, hair tonics, and tobacco. It is responsible for the characteristic odor of cashmere shawls, which are always shipped in patchouli-scented containers.

Champaca.—Champaca oil, which constitutes one of the most famous perfumes of India and other oriental countries, is obtained from *Michelia Champaca*, a large handsome tree of the eastern

tropics. The conspicuous yellow flowers are very fragrant and are much worn by the natives. The oil is distilled from the flowers and rivals ylang-ylang in its delicious fragrance.

Several of the gum resins, chiefly frankincense and myrrh, which have already been discussed, have been used in perfumery for thousands of years.

Garden flowers, in addition to those mentioned above, which are extensively cultivated for their perfume include heliotrope (*Heliotropium peruvianum*), lily of the valley (*Convallaria majalis*), jonquil (*Narcissus Jonquilla*), mignonette (*Reseda odorata*), narcissus (*Narcissus Tazetta*), and tuberose (*Polianthes tuberosa*).

Other sources of essential oils used in perfumes will be discussed later in connection with other topics. Among these are anise, caraway, cassia, cinnamon, clove, lemon, peppermint, thyme, wintergreen, and zedoary.

ESSENTIAL OILS USED IN OTHER INDUSTRIES

Camphor

Camphor is the most important of the essential oils used in industry. Commercial camphor, known as camphor gum, consists of tough, white, translucent masses or granules with a penetrating odor and pungent, aromatic taste. It is solid at ordinary temperatures, thus bearing the same relation to the other essential oils that vegetable fats do to the fatty oils. It volatilizes very slowly.

Camphor is obtained by distillation of the wood of the camphor tree (*Cinnamomum camphora*). This tree is very tall and striking in appearance (Fig. 88) with shiny, dark, evergreen leaves. It is a native of China, Japan, and Formosa, but has been widely introduced into tropical and subtropical regions elsewhere, chiefly as an ornamental plant. The Japanese have a virtual monopoly of the camphor industry, since 75 per cent of the product comes from Formosa. The earlier crude methods of obtaining camphor were very destructive and the existence of the trees was threatened. Now only trees 50 years of age or older are used, and every stage in the process is carefully supervised. The wood is reduced to chips or ground to a fine powder and the leaves are also ground up. This material is then distilled with steam for about 3 hours, and the crude camphor crystallizes on the walls

of the still. This is removed and must be purified before it is ready for market.

The United States is a large consumer of camphor. Because of its importance in this country, the growing of camphor has been experimented with and today camphor is a crop of increasing prominence, especially in Florida. The trees are propagated

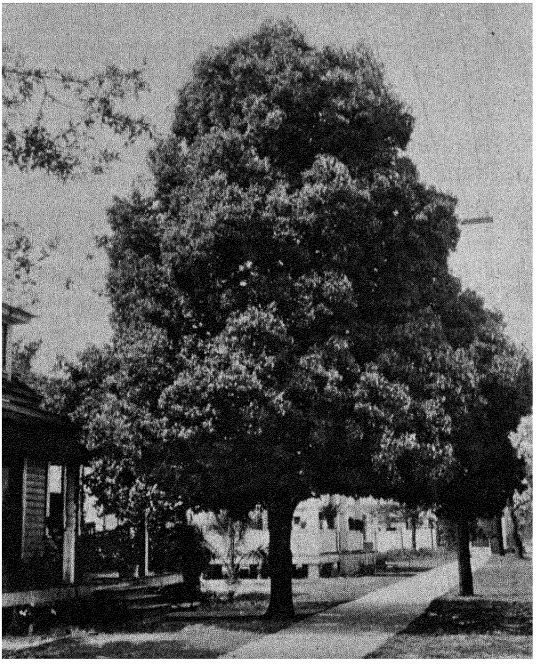


FIG. 88.—A camphor tree (*Cinnamomum camphora*) in Florida. (*Photo by U.S. Forest Service.*)

from seed in nurseries and are later transplanted. Nearly 10,000 acres are now devoted to camphor growing. Twigs and leaves are utilized for distillation rather than the old wood. Clippings can be made from the trees when they are three or four years old, and several times a year thereafter.

The principal use of camphor is in the manufacture of celluloid and the various nitrocellulose compounds. Camphor also has a wide range of medicinal uses, both internally and externally. It is also used in perfumery.

Borneo camphor, which is obtained from *Dryobalanops aromatica* of the East Indies, has been used as a substitute. A synthetic

camphor can be made from oil of turpentine and several other substances, but it is little used.

Miscellaneous Oils

Several of the essential oils have a high refractive index and are valuable as clearing agents in the preparation of permanent microscopic mounts and for use with oil-immersion lenses. The most important of these is *cedar oil.* This is obtained by distilling the wood of the red cedar (*Juniperus virginiana*), a common tree of the eastern United States. Chips and other waste from the lead-pencil industry are often utilized. Cedar oil is also used in perfumery and soaps and to adulterate sandalwood oil Clove and bergamot oils are also used as clearing agents.

Essential oils are useful as solvents in the paint and varnish industry. The most important of such oils, oil of turpentine, has already been discussed. Various other volatile oils, chiefly eucalyptus oil from *Eucalyptus dives*, are employed in the flotation process for the separation of minerals from their ores. Still other oils are used in the preparation of various cleaning materials and for many other industrial purposes.

1935 IMPORTS OF IMPORTANT ESSENTIAL OILS

	Pounds		Pounds
Amber	2,150	Lavender	98,051
Anise	212,998	Lemon	131,043
Bergamot	99,270	Lemon grass	365,457
Bitter almond	13,685	Linaloe	115,121
Cananga (ylang-ylang)	63,488	Lime	63,974
Cajeput	15,189	Neroli	694
Camphor, crude	1,541,936	Orange	161,154
Camphor, refined	1,256,278	Origanum	93,146
Camphor oil	1,181,631	Orris	273
Caraway	14,275	Otto of roses, oz.	35,810
Cassia	259,659	Palmarosa	7,752
Cedrat	734	Patchouli	4,924
Cinnamon	191,483	Petitgrain	56,004
Citronella	1,682,574	Rosemary	233,423
Clove	8,468	Sandalwood	2,751
Eucalyptus	365,357	Spike lavender	128,133
Geranium	123,261	Thyme	14,317
Juniper	9,441	Vetiver	6,391

CHAPTER IX

FATTY OILS AND WAXES

FATTY OILS

Another type of oil that occurs in plants is the fatty oil. The fatty oils are also called fixed oils because, unlike the essential oils, they do not evaporate or become volatile, and they cannot be distilled without being decomposed. Chemically these vegetable fatty oils are close to animal fats. They consist of glycerin in combination with a fatty acid. The so-called oils are liquid at ordinary temperatures and usually contain oleic acid. The fats, on the other hand, are solid at ordinary temperatures and contain stearic or palmitic acid. The fatty oils are insoluble in water, but soluble in various organic solvents. When fats break down, they yield the fatty acids and glycerin, of which they are composed, and usually develop a rancid odor and taste. When a fat is boiled with an alkali, it decomposes and the fatty acid unites with the alkali to form soap. If potash or lye is used, a soft soap is obtained; if soda is used, a hard soap is the result.

Fatty oils are produced in many families of plants, both tropical and temperate. They are stored up, often in large amounts, in seeds (Fig. 89) and, to a less extent, in fruits, tubers, stems, and other plant organs; they are often associated with proteins. This type of reserve food material is available as a source of energy for the processes involved in the germination of the seed. The fatty oils are bland and lack the strong taste and odor and the antiseptic qualities of the essential oils. Consequently they are available as food for man. These edible oils contain both solid and liquid fats and form indispensable articles of human food. The demand for edible oils has so increased in recent years that various processes have been developed whereby the nonedible oils have been rendered available. This is usually done by hydrogenation, the adding of hydrogen.

The method of extraction of the oils varies in different cases. Usually the seed coats have to be removed, and then the material

is reduced to a fine meal. The oils are removed by solvents or by subjecting the meal to hydraulic pressure. This latter method is used for the edible oils. The residue is rich in proteins and is valuable as a fertilizer and as a cattle feed. The pressure causes the cell walls to break and the fats escape. The extracted oils

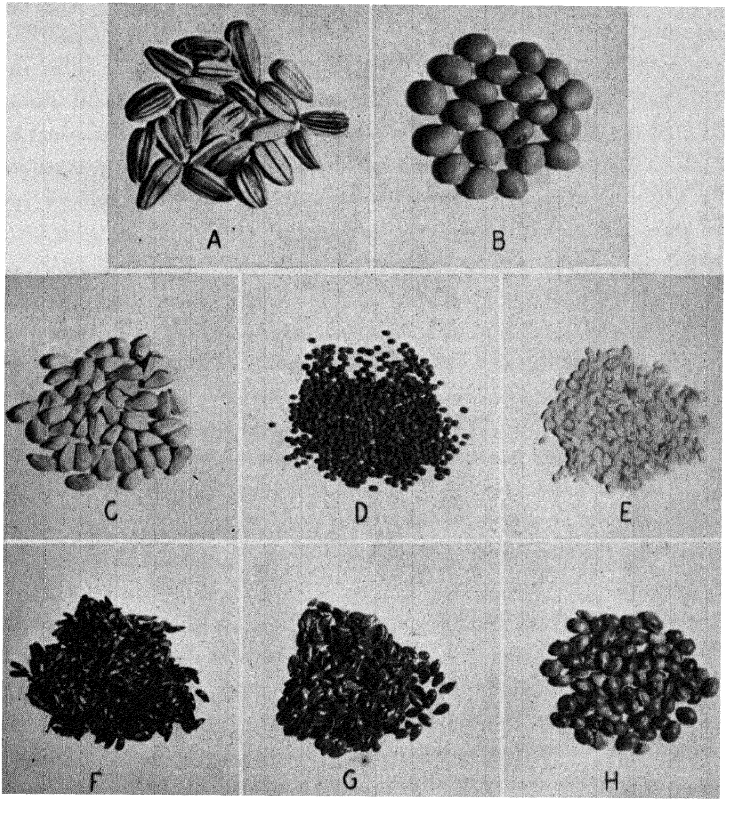


FIG. 89.—A group of oil seeds. *A*, sunflower (*Helianthus annuus*); *B*, soybean (*Glycine Soja*); *C*, safflower (*Carthamnus tinctorius; D*, rape (*Brassica Napus*), *E*, sesame (*Sesamum indicum*); *F*, niger (*Guizotia abyssinica*), *G*, flax (*Linum usitatissimum*); *H*, hemp (*Cannabis sativa*).

are filtered and may be further purified. The higher grades are edible, and the lower are used in the industries. The increasing demand for these industrial oils since the World War has led to the improvement of methods of cultivation and preparation, and also to a search for new sources the world over. Fatty oils also have a medicinal value.

Four *classes of vegetable fatty oils* are recognized: (1) drying oils, (2) semidrying oils, (3) nondrying oils, and (4) fats or tallows. The drying oils are able to absorb oxygen and on exposure dry into thin elastic films. These oils are of great importance in the paint and varnish industries. The semidrying oils absorb oxygen slowly and only in limited amounts. They form a soft film only after long exposure. Some of these oils are edible; others are used as illuminants or in making soap and candles. The nondrying oils remain liquid at ordinary temperatures and do not form a film. These oils are edible, and can be used for soap and lubricants. The fats are solid or semisolid at ordinary temperatures. They are edible and useful in the manufacture of soap and candles.

Drying Oils

Linseed Oil.—The seed (Fig. 89, *G*) of the flax plant (*Linum usitatissimum*) has long been the source of the most important of the drying oils. Seeds that are immature, or otherwise unfit for germination, are collected and stored for several months. The impurities are removed and the seeds are ground to a fine meal. The oil is extracted by pressure with heat, or by using naphtha or other solvents. Linseed oil varies from yellow to brownish in color and has an acrid taste and smell. On oxidation it forms a very tough elastic film. This drying property is increased by heating the raw oil to 65°C., producing the so-called boiled linseed oil. Linseed oil is used chiefly in the making of paints and varnishes, linoleum, and printer's ink. After extraction the oil cake is used as a cattle feed. Linseed is produced commercially chiefly in Argentina, where over 3,000,000 acres are devoted to flax cultivation. Russia, India, Uruguay, Poland, Canada, and the United States also produce a considerable quantity. Minnesota and the Dakotas are the centers of seed-flax production in this country, the annual yield amounting to about 15,000,000 bu. Until 1850 flax was grown in the United States for its fiber, the uses and nature of which have already been discussed. At the present time most of the flax is grown for the seed.

Chinawood and Tung Oils.—Chinawood oils, widely used in the varnish industry as a substitute for linseed oil, are obtained from the nuts of two Chinese species of *Aleurites*, *A. montana*,

the mu tree, restricted to southeastern China, and *A. Fordii*, the tung-oil tree (Fig. 90), a species native to central and western China. The United States uses so much tung oil that trees of the latter species have been introduced and are now being grown with great success in Florida. The trees are a profitable

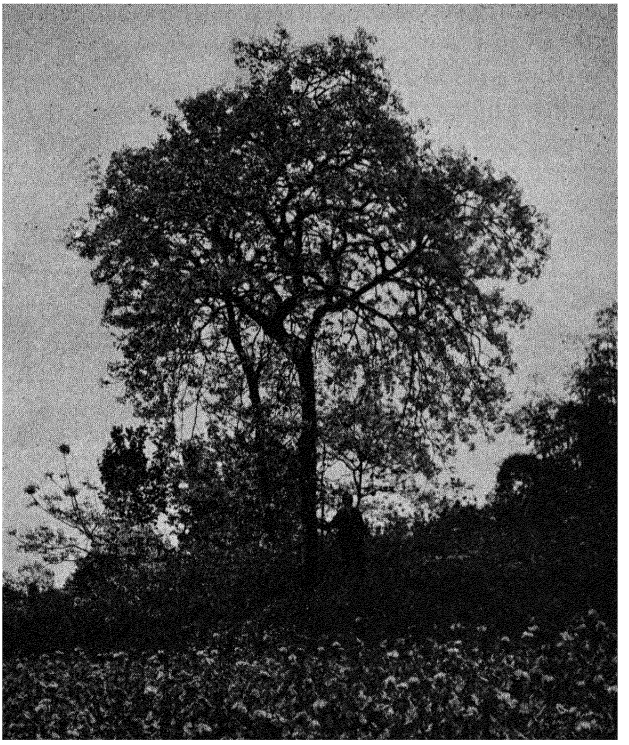


FIG. 90.—A tung-oil tree (*Aleurites Fordii*) growing in a field of opium poppies. Fengtu Hsien, western Szechuan, China. (*Photo by E. H Wilson; courtesy of the Arnold Arboretum.*)

source of income, for they will grow on soils unsuitable for other types of agriculture. They yield oil from the fourth to tenth year. Tung and chinawood oils are very similar in nature. They have almost revolutionized the varnish industry, for they yield a quick-drying varnish much less liable to crack than that obtained with kauri gum and other hard resins. They are also used for paints, linoleum, leather dressings, and waterproof prim-

ing for cement. Chinawood oil is a good preservative and very resistant to weathering, so it is particularly valuable for outside paints. Boatmen prefer it as it is little affected by salt water. These oils are the most rapid of the drying oils. The oil cake is poisonous and cannot be used for food.

Candlenut Oil.—This oil is obtained from the hard-shelled seeds or "nuts" of *Aleurites moluccana*, which is native to Malaya and the Pacific Islands and is cultivated elsewhere. It is a good drying oil and is much used as a substitute for linseed oil in making paints, varnishes, lacquer, linoleum, and soft soap

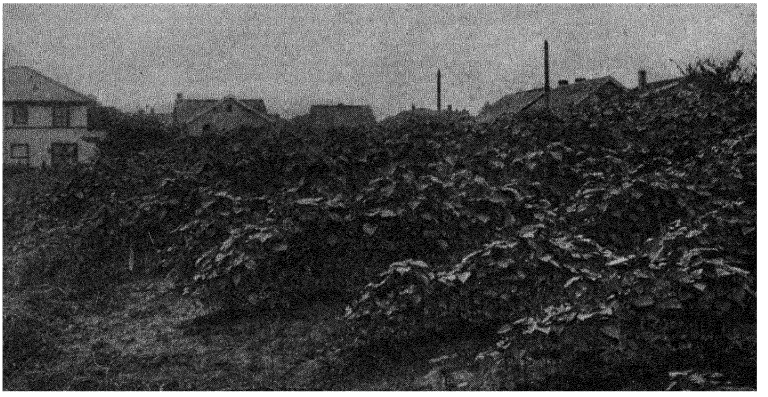


FIG. 91.—Young plants of *Perilla frutescens*, the source of perilla oil.

and as a preservative for the hulls of vessels. The nuts are used in Hawaii and the other Polynesian islands for illumination, hence the name candlenut. The oil cake is poisonous and serviceable only as a fertilizer.

Perilla Oil.—Perilla oil is obtained from the seeds of *Perilla frutescens*, an aromatic annual 3 to 5 ft. in height with numerous branches (Fig. 91). The plant, a native of northern India, China, and Japan, is extensively cultivated in the Orient, particularly in Japan. It matures slowly and has to be harvested before it is quite ripe or the seeds fall from the capsules. The oil, which is expressed from roasted and crushed seeds, is edible and has been used for food purposes from earliest time. The industrial uses of perilla oil, however, are much more important. It is used in the manufacture of the famous Japanese oil papers, cheap

lacquer, paper umbrellas, waterproof clothes, artificial leather, and printer's ink. The United States imports a large amount for use in the paint and varnish industries as a substitute for linseed oil, even though the quality is inferior.

Walnut Oil.—Mature and old kernels of the English walnut (*Juglans regia*) yield a drying oil used for white paint and artist's oil paints and for printing ink and soap. Hot-pressed oil is best adapted for these purposes. The fresh or cold-pressed oil has a pleasant smell and nutty flavor and is edible.

Sunflower Oil.—The seeds (Fig. 89, *A*) of the common sunflower (*Helianthus annuus*), a native of Peru, contain an oil that is used for varnishes and soap and for edible purposes. The plant is cultivated for the oil in many parts of the world.

Poppy Oil.—An important drying oil is obtained from the seeds of the opium poppy (*Papaver somniferum*). This famous drug plant is grown for the seeds in northern France and Germany and in India. The first pressing yields an edible white oil, while the second furnishes a reddish oil used for lamps, soap, and, after bleaching, for oil paints.

Niger Seed Oil.—This pale-yellow oil is obtained from the seeds (Fig. 89, *F*) of *Guizotia abyssinica*, an annual plant native to Abyssinia. It is extensively cultivated in India, Germany, and the West Indies. The higher grades have a pleasant aromatic odor and are used for food, while the poorer grades are used as illuminants and for soap. This oil is but little used in the United States.

Many other species furnish drying oils of some commercial importance. Among them may be mentioned **camelina oil,** from *Camelina sativa*, grown in Holland, Germany, and other European countries and used for soap and as an illuminant; **hemp-seed oil** from *Cannabis sativa* (Fig. 89, *H*), also grown in European countries for the oil, used for soap, paints, and varnishes and as a lamp oil; and **safflower oil** from *Carthamnus tinctorius*. The latter plant, already mentioned as the source of a dye, is extensively cultivated in Egypt, India, and the Orient and to some extent in the United States for its oil-containing seeds (Fig. 89, *C*). The oil is used for soap and varnishes and as an edible oil and illuminant. The seeds of *Sapium sebiferum*, *Argemone mexicana*, *Hevea brasiliensis*, and *Manihot Glaziovii* also yield drying oils of commercial importance.

Semidrying Oils

Cottonseed Oil.—This is the most important of the semidrying oils and is used as the standard of comparison. The United States is the chief producer, but nearly all the cotton-growing countries contribute to some extent. Over 115,000,000 gal. of the oil are expressed. The industry has been developed since about 1880, prior to which time cotton seeds were waste products. The seeds are carefully cleaned and freed from impurities and the linters and hulls are removed. The kernels are then crushed and heated and are finally subjected to hydraulic pressure. The oil is pumped into tanks where the impurities settle out. The pure oil is of great value as a salad and table oil and for making oleomargarine and lard substitutes. The residue is the source of various products that have a wide range of industrial uses. Among these may be mentioned soap, washing powders, oilcloth, artificial leather, insulating materials, roofing tar, putty, glycerin, and nitroglycerin. Cottonseed meal is important as a foodstuff and fertilizer.

Corn Oil.—The kernels of maize or Indian corn contain about 50 per cent of oil present in the embryo. Until recently the embryos were a waste product of the milling industries, but today the production of corn oil is of increasing importance. It can be used for nearly all the purposes to which any oil is put. Refining methods have made possible the utilization of 75 per cent of the oil for edible purposes. The familiar "Mazola" oil can be used for cooking, in bakeries, and for mixing with other oils. The crude oil has many industrial uses, such as the manufacture of rubber substitutes, soaps, and cheap paints. Like cottonseed oil, it is of little use as a lubricant.

Soybean Oil.—The soybean (*Glycine Soja*), indigenous to Eastern Asia, and a food plant of paramount importance in that region, also yields a valuable oil, which is extracted from the seeds (Fig. 89, *B*) by expression or by treating ground seeds with some solvent. It is midway between linseed oil and cottonseed oil in its characteristics and so is sometimes classed as a drying oil and sometimes as a semidrying oil. After refining, soybean oil can be used as a salad oil and for other edible purposes. Inferior grades are used in the manufacture of candles, soap, varnish, printing ink, etc. Its industrial uses are constantly increasing in

this country and in Europe. In recent years soybeans have become a crop (Fig. 92) of major importance in American agriculture.

Sesame Oil.—This oil, known also as gingelly oil, is the product of the seeds (Fig. 89, *E*) of an annual herb, *Sesamum indicum*. It is the chief oil of India and has been cultivated there from remote times. Today over 3,000,000 acres are devoted to this



FIG. 92.—A field of soybeans (*Glycine Soja*) in Connecticut. (*Courtesy of the Connecticut Agricultural Station in New Haven*)

crop. Its use has spread to other tropical regions and it is now grown in many Asiatic (Fig. 93) and African countries. Sesame oil was brought to the United States by the slaves, and the Southern negroes grow the plant to this day. The seeds contain about 50 per cent oil, which is easily extracted by cold pressure. The finer grades are tasteless and nearly colorless and are used as a substitute for olive oil in cooking and in medicine. European countries use enormous quantities, as it is a compulsory addition to margarine and other food products. Marseilles imports over 100,000,000 lb. The poorer grades are used for soap, perfumery, and rubber substitutes, and to some extent as lubricants. In India the oil is used for anointing the body, as fuel for lamps, and as food. The oil cake is a good cattle food.

Colza and Rapeseed Oils.—The seeds of several species of *Brassica*, particularly *B. campestris*, *B. Napus*, and *B. Rapa*, yield oils with similar characteristics which are classified commercially as colza or rape oils. The rape (*B. Napus*) is extensively cultivated in Europe, and also in India and China, for its oil seeds (Fig. 89, *D*). Refined colza oil is edible, and the crude oil is used in lamps, as a lubricant, in the manufacture of soaps and rubber substitutes, and for oiling woolen goods. Cold-pressed

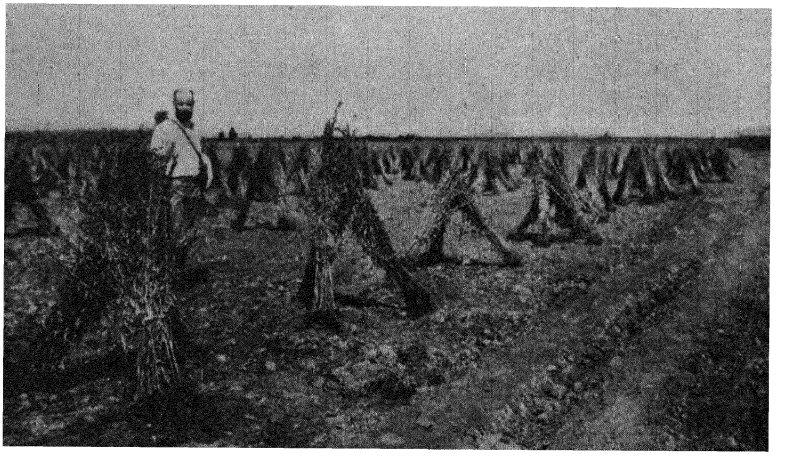


FIG. 93.—A field of sesame (*Sesamum indicum*) which has been pulled and stacked to allow the pods to dry. Pangkwangchen, Shensi, China. (*Photo by F. N. Meyer; courtesy of the Arnold Arboretum.*)

rape oil is also edible and is much used for greasing loaves of bread before baking. Its industrial uses are similar to those of colza oil.

Kapok Oil.—The seeds of the kapok tree, already mentioned, are the source of a semidrying oil of some importance. The higher grades are used for oleomargarine and the lower in soapmaking.

Nondrying Oils

Olive Oil.—Olive oil, obtained from the fruits of the olive (*Olea europaea*), is the most important of the nondrying oils. The tree is a small evergreen and is cultivated chiefly in the Mediterranean countries and to some extent in Australia, South

Africa, and Mexico. The United States now produces about 5,000,000 lb. in California, Arizona, and Florida but has to import twenty times as much more. The oil is squeezed from the pulp either by hand or mechanically. The finest grades are obtained by the former method. These oils are golden yellow, clear and limpid, odorless, and edible. Inferior grades have a greenish tinge and are used for soapmaking and as lubricants. The poorest grades are obtained by the use of solvents after several pressings. Fully ripe olives give the largest yield. Olive oil is

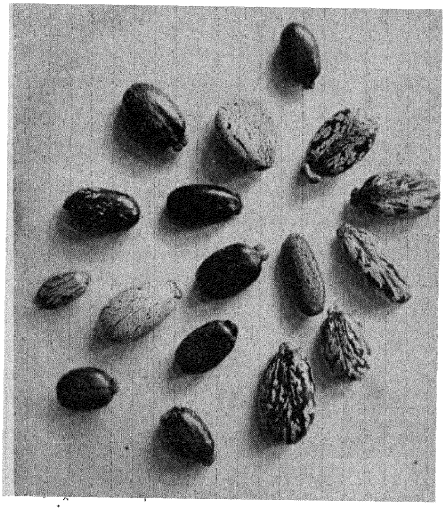


FIG. 94.—Castor-bean seeds (*Ricinus communis*), the source of castor oil. (*Reproduced by permission from Youngken, Textbook of Pharmacognosy, P. Blakiston's Son & Company.*)

one of the most important food oils, as it will keep for a long time and becomes rancid only when exposed to the air.

Peanut Oil.—Peanut oil is obtained from the seed or "nut" of the common peanut (*Arachis hypogaea*), to be discussed later. The chief sources of the world's supply are the United States, West Indies, Africa, India, and China. The expression of the oil is carried out in Europe. The nuts are shelled, cleaned, crushed, and pressed. Cold-pressed oil has the best flavor and is nearly colorless. This is edible and is used as a salad oil, for packing sardines, for margarine, and as an adulterant for olive oil. Inferior grades, expressed at higher temperatures, are used for soapmaking, lubricants, and illuminants. The cake is one of

the best stock feeds as it has a higher protein content than any other oil cake.

Castor Oil.—This familiar oil comes from the seeds of *Ricinus communis*, a coarse erect annual herb cultivated everywhere in temperate and tropical regions. In the United States it is a favorite ornamental plant. The seeds, which are very characteristically marked (Fig. 94), contain 25 to 40 per cent of a thick colorless or greenish oil. After expression the oil is boiled with water and filtered to remove the mucilage and proteins that are present. The chief use of castor oil is in medicine, where it acts as a purgative. Recently it has come into prominence as a lubricant for airplane engines. It is also used for soap, in preserving leather, and as an illuminant. The oil cake is poisonous, but makes a very good fertilizer.

Other nondrying oils include **croton oil**, to be discussed under drug plants; **tea-seed oil** from *Camellia Sasanqua;* **oil of ben** from *Moringa oleifera;* **pistachio-nut oil** from *Pistacia vera;* and **rice oil** from *Oryza sativa.* Nondrying oils are also obtained from almond fruits;,the kernels of apricots, peaches, and plums; pili nuts; and the seeds of grapes, tomatoes, and black and white mustard.

Vegetable Fats

Coconut Oil.—This is one of the most extensively used of the fatty oils. It is obtained from the dried meat of the coconut (*Cocos nucifera*). This oil is pale yellow or colorless and is solid below 74°F. After the nuts have been harvested, the husks are removed and the nuts split open and dried by either natural or artificial heat. The dried meat, or copra as it is called, is then easily removed. This is ground up and pressed by various methods. The cake is sometimes put through hydraulic presses and still more oil is removed. The yield is about 65 to 70 per cent. Recently, fresh meat has been utilized in the presses and this yields 80 per cent or more. The cold-pressed oil is edible and is now much used for food products, chiefly margarines. It is particularly well adapted for this purpose as it is solid at ordinary temperatures; many artificial butters prepared from it are now on the market. Coconut oil has long been used for the best soaps, cosmetics, salves, shaving creams, shampoos, and other toilet preparations. It is also useful as an illuminant. The cake is an excellent stock food. About 500,000 tons of coco-

nuts are used annually for the oil. Copra is produced chiefly in the Straits Settlements, Ceylon, India, Polynesia, the Philippine Islands, and the West Indies. Most of the oil is expressed in Europe, the United States, and Japan, although Ceylon and India export large amounts.

Palm Oil.—Palm oil is a white vegetable fat, solid at ordinary temperatures, which is obtained from the nuts of the oil palm

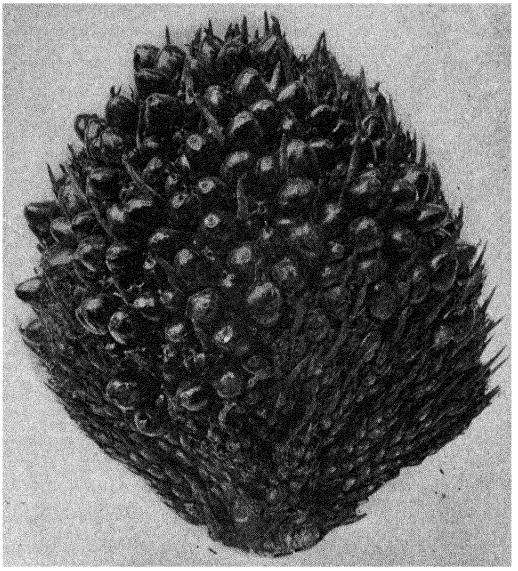


FIG. 95.—Fruit of the oil palm (*Elaeis guineensis*). Both the fibrous pulp of the fruits and the kernels yield an important vegetable fat. (*Photo by the Philippine Bureau of Forestry.*)

(*Elaeis guineensis*). This tree is a native of Western Africa but has spread all through the tropics and now covers enormous areas. It is frequently cultivated. The oil palm is a very productive tree. It begins to bear at the age of 5 to 6 years, reaches full bearing at 15, and continues until 60 or 70 years of age. Each tree bears 10 bunches of 200 nuts a year. The fibrous pulp of these fruits (Fig. 95) contains 55 to 60 per cent of fat. The oil is obtained chiefly by crude native methods. It is yellow-orange or brownish red in color, and, although eaten by the natives, it is used chiefly in the soap and candle industries. Over 200,000 tons

of the oil enter the world trade, coming from Sumatra, Java, and the west coast of Africa.

The kernels of the oil palm yield a different oil, which is white in color and more valuable. **Palm-kernel oil** is used in the margarine industry for it has a pleasant odor and nutty flavor. It is also used for soap and candles. The natives express a little oil for their own use, but the kernels are usually shipped to the oil mills of Europe and the United States where the oil is extracted by hydraulic presses or by solvents. Over 500,000 tons of the kernels are used. Palm-kernel cake is a good food for cattle.

Vegetable Fats of Minor Importance.—These include:

Cocoa Butter.—This white or yellowish fat with a chocolate odor and flavor is expressed from the beans of the cacao or cocoa (*Theobroma Cacao*) during the process of making cocoa. It is firm at ordinary temperatures. Although used somewhat in making chocolate, its chief use is for cosmetics and in perfumery and medicine.

Carapa Fat.—This thick white or yellow oil is obtained from the seeds of several species of the genus *Carapa* and is used for soap. The South American natives use the oil from *C. guianensis* to grease their skins and drive off insects. *C. moluccensis* is a native of East Africa, India, Ceylon, and the Moluccas. Carapa oil is also used as an illuminant.

Shea Butter.—The seeds of *Butyrospermum Parkii*, an African tree, furnish shea butter, a greenish-yellow fat with a pleasant odor and taste. The fat is edible, and is also used mixed with, or as a substitute for, cocoa butter in chocolate manufacture. Inferior grades are utilized for soap and candles.

Mowra Fat.—Several species of the genus *Madhuca*, *M. indica*, *M. longifolia*, and *M. butyracea*, are the source of various Indian products, which are known as mowra fat, bassia fat, mahua butter, or illipe butter. The trees grow wild and are also extensively cultivated. The kernels contain 55 to 65 per cent of a soft yellow oil widely used locally for cooking and tallow. Over 66,000,000 lb. are exported to Europe for use as a margarine and chocolate fat and in soap manufacturing. The cake is unfit for food but makes a good fertilizer.

Borneo Tallow.—This fat is obtained from *Shorea aptera* and several other species of the same genus native to the East Indies. The kernels, which contain 50 to 70 per cent of fat, are dried and

expressed by the inhabitants for their own use or are exported to Europe for soapmaking.

Chinese Vegetable Tallow.—This material occurs as a thick layer of hard white fat on the seeds (Fig. 96) of a Chinese tree, *Sapium sebiferum.* After proper treatment the tallow is used in soap and candle manufacture. The seeds of this tree contain a drying oil that is of some value.

Cohune Oil.—The nuts of the cohune palm (*Orbignya Cohune*), a native of South and Central America, contain 40 per cent of a firm yellow fat, similar to coconut oil in its characteristics. Over 2,000,000 acres of this tree occur in British Honduras alone, and

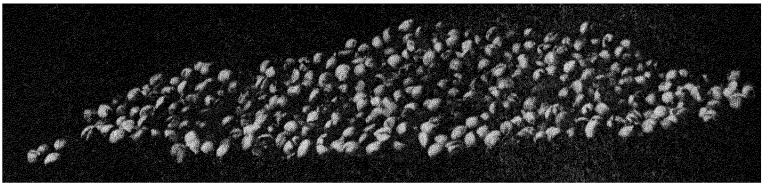


FIG. 96.—The seeds of *Sapium sebiferum*, the source of Chinese vegetable tallow. Ochany, western Hupeh, China. (*Photo by E. H. Wilson; courtesy of the Arnold Arboretum.*)

the yield is from 1000 to 2000 nuts per tree. In the past the difficulty of finding a suitable machine to crack and crush the extremely hard walls of the nut have prevented a more widespread use of the fat. Recently effective machines have been devised and the fat is becoming of increasing importance in margarine manufacture and soap making. Several allied species of palms also furnish fats of some use.

Nutmeg Butter.—The seeds of the nutmeg (*Myristica fragrans*) and allied species contain about 40 per cent of a yellow fat with the flavor and consistency of tallow. Nutmegs that are unfit for use in the spice trade are roasted and powdered and the oil is extracted between warm plates. Several varieties of nutmeg butter are on the market, all used for ointments or for candles. Mace yields a similar material.

Locally many other vegetable fats are of some importance. Among such may be mentioned *pongam oil* from the seeds of *Pongamia pinnata,* used for illumination and medicine in India and Ceylon; and *macassar oil* from the seeds of *Schleichera oleosa,*

a soft yellowish-white fat used in India, Ceylon, and the East Indies for cooking purposes, as a hair oil, and for illumination.

Chaulmoogra oil will be discussed under medicinal plants.

WAXES

Waxes are usually found on the epidermis of leaves and fruits, where, because of their impervious character, they serve to pre-

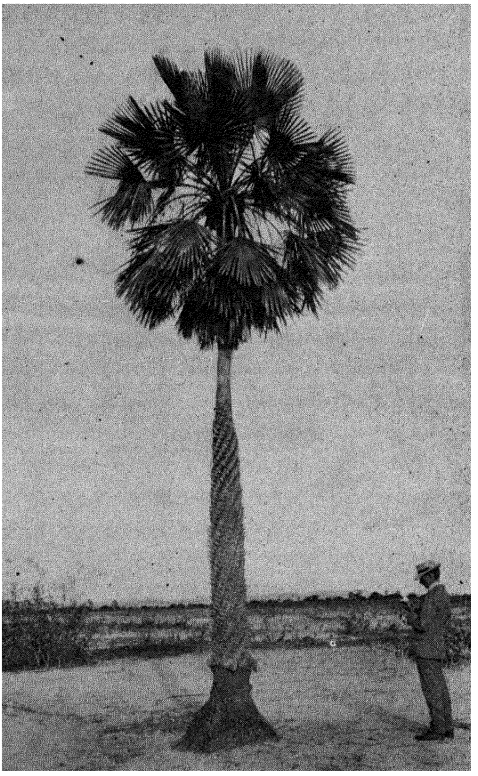


FIG. 97.—The carnauba palm (*Copernicia cerifera*) in Brazil. This palm yields the most important vegetable wax. (*Reproduced from Pan American Bulletin, March*, 1932.)

vent too great loss of water through transpiration. Waxes are harder than fats and have a higher melting point. They do not become rancid and are less easily hydrolyzed. In chemical composition waxes are quite similar to fats, but are esters of monohydric acids rather than glycerides. Only a few are of commercial importance. Among these may be mentioned:

Carnauba Wax.—This is the most important wax and occurs as an exudation on the leaves of the wax palm (*Copernicia cerifera*), a native of Brazil and other parts of tropical South America (Fig. 97). Young leaves are gathered before they are fully open and are dried in the sun. The powdery wax is scraped off and placed in boiling water. The wax forms a layer on the surface and, after cooling, it is removed and formed into cakes for shipment. Several grades are recognized. The crude wax is greenish gray in color and very hard and has a high melting point. It is used in the manufacture of candles, high-luster wax varnishes, phonograph records, and many other products. A similar wax from *Ceroxylon andicola* of the South American Andes is often used as a substitute. In this species the wax is deposited on the trunk rather than on the leaves.

Candelilla Wax.—This wax is obtained from the stems of *Pedilanthus Pavonis* and *Euphorbia antisyphilitica*, desert shrubs of Mexico and Texas. The wax is removed by hot water or solvents and is used for the same purposes as carnauba wax.

Myrtle Wax.—The berries of the wax myrtle (*Myrica cerifera*) and the bayberry (*M. carolinensis*), both native to the eastern United States, are covered with a thick layer of wax. This is removed by boiling in water, and is used for candle manufacture.

Commercial wax is also obtained from the berries of the Japanese wax tree (*Rhus succedanea*) and the leaves of the raphia palm, sugar cane, and esparto.

SOAP SUBSTITUTES

A considerable number of plants contain natural products that can be utilized as soap substitutes. These are the saponins, a group of water-soluble glucosides. Plants that contain saponins yield a soap froth in water, form emulsions with fats and oils, and are capable of absorbing large amounts of gases, such as carbon dioxide. The use of these plants and their products in industry is correlated with the above properties. In addition to the few that are commercially important, there are numerous wild species that are used locally. The most important saponin-containing plants are:

Soapbark.—The soapbark tree (*Quillaja Saponaria*) grows on the western slopes of the Andes in Peru and Chili. The commercial material is the dried inner bark, which is removed after

the outer bark has been shaved off. The saponin content of the bark is 9 per cent. Soapbark forms a copious lather in water and is used in washing delicate fabrics. In medicine it is used to some extent as an expectorant and emulsifying agent. However, it is a dangerous drug to take internally, as it is very toxic and tends to dissolve the blood corpuscles. For this reason its use to increase the foaming power of beer and other beverages, owing to its ability to dissolve gases, is being discouraged. Soapbark is also a good cutaneous stimulant and is much used in hair tonics.

Soapwort.—The familiar old-time garden plant known as Bouncing Bet or soapwort (*Saponaria officinalis*) contains a considerable amount of saponin. This plant, a native of Eurasia, is now naturalized in the United States. When placed in water the leaves produce a lather which is utilized for washing silks and woolens. It not only cleanses, but imparts a luster as well.

Soapberries.—Soapberries are the fruits of a tropical American tree, *Sapindus Saponaria*. They are used as soap substitutes and in the preparation of hair tonics.

Soaproot.—The bulbs of the California soaproot (*Chlorogalum pomeridianum*) yield a good lather and are much used locally in washing fabrics.

1935 IMPORTS OF IMPORTANT FATTY OILS, WAXES, AND SAPONINS

Oil Seeds and Other Raw Materials

	Pounds		Pounds
Apricot and peach kernels	65,482	Perilla	2,782,566
Castor beans	77,048,961	Poppy	8,392,532
Copra	454,134,203	Rape	29,515,220
Flax	983,341,072	Sesame	146,394,158
Hemp	116,681,757	Soybean	248,887
Kapok	12,656,625	Sunflower	667,402
Palm nuts and kernels	50,072,548	Tung nuts	1,977

Inedible Expressed Oils

Castor	258,343	Perilla	72,327,864
Coconut	353,406,263	Poppy	13,716
Croton	3,582	Rape and colza, gal	8,039,719
Hempseed	339,662	Sesame	11,088
Linseed	2,232,451	Soybean	14,248,574
Nut	15,457,661	Sweet almond	212,290
Olive	53,540,670	Sunflower	207,171
Palm kernel	50,592,641	Tung	120,058,817
Palm nut	297,579,208	Vegetable tallow	80,696

Edible Expressed Oils

Cocoa butter	12,460	Palm kernel	7,977,812
Corn	25,746,090	Peanut	80,723,225
Cottonseed	166,687,367	Sesame	360,058
Olive	70,788,530	Sunflower	37,051,732

Oil Cake

Copra	103,737,670	Linseed	20,979,647
Cottonseed	59,743,572	Peanut	6,572,394
Hempseed	493,213	Soybean	107,463,044

Waxes and Saponins

Carnauba wax	10,420,568	Soapbark	259,612
Other waxes	4,650,360		

CHAPTER X

SUGARS, STARCHES, AND CELLULOSE PRODUCTS

SUGARS

Sugars are manufactured by green plants and so are to be found in small amounts, at least, in all individuals. So much of the manufactured product, however, is used directly in the metabolism of the plant that comparatively little is accumulated. Storage sugars are to be found in roots, as in the case of beets, carrots, parsnips, etc.; in stems, as in sugar cane, maize, sorghum, and the sugar maple; in flowers, such as the palm; in bulbs like the onion; and in many fruits. Several types of sugar are to be found, chief among which are sucrose or cane sugar, glucose or grape sugar, and fructose or fruit sugar. These sugars obviously serve as a reserve food supply for the plant.

Sugar likewise is one of the most necessary foods for man. The day has passed when it was considered merely as a luxury to be used for flavoring purposes. It constitutes a perfect food as it is in a form that can be readily assimilated by the human body. Its chief value is as an energy producer, and it is particularly well adapted for use after any type of muscular exertion. Although primarily a food, such a vast industry has been built up in connection with the extraction of the sugar from plant tissues, its purification, and refining, that it seems best to consider sugar as an industrial plant product.

Sugar is one of the most valuable products of the plant world. It is surpassed in importance only by wheat, corn, rice, and potatoes, and over 30,000,000 tons are produced annually with a value of $1,500,000,000. Considering its importance, it is surprising that the sources from which it is obtained are so few in number. Only the sugar cane, sugar beet, sugar maple, maize, sorghum, and a few palms are of commercial interest. In all of these sucrose is the type of sugar stored.

Sugar Cane

The chief source of sugar at the present time is the sugar cane (*Saccharum officinarum*). This plant is a vigorous and rapid-

growing grass, which reaches a height in cultivation of 8 to 12 ft. or more and a diameter of about 2 in. It grows in clumps (Fig. 98), with bamboolike stems arising from large rootstalks and with very ornamental feathery plumes of flowers. The stem is solid with a tough rind and numerous fibrous strands, and con-



FIG. 98.—A field of sugar cane (*Saccharum officinarum*).

tains about 80 per cent of juice, the sugar content of which varies greatly.

The sugar cane is not known in a wild state. The plant was probably first domesticated in Southeastern Asia or the East Indies from some wild ancestor native to that region. By 327 B.C. it had become an important crop in India. It reached Egypt in 641 A.D., and Spain in 755 A.D. Since that time sugar cane has gradually been introduced into all moist tropical and semitropical regions. The Spaniards and Portuguese were the

great disseminators of the plant into the New World. They carried it to Madeira in 1420, and to America by the beginning of the following century. Within another hundred years it had spread all over the West Indies and Central and South America. Sugar cane was first introduced into the United States in Louisiana in 1751. The name "sugar" comes from the Sanskrit "sarkara," meaning gravel, and refers to the crude sugar, which was the only kind known for centuries.

Sugar cane is the greatest export crop of the tropics and is unaffected by many of the conditions that influence other crops. It will grow well in any moist hot region where the average rainfall is 60 in. or more a year and where the temperature does not fall below 80°F. The methods of cultivation vary considerably in the different countries where the plant is grown. In general, however, the practice is fundamentally the same. Extensive, flat, low-lying fields are utilized and these are plowed deeply. The sugar cane is propagated by cuttings 8 to 10 in. in length made from the upper joints of old canes. These cuttings, known as *seed*, are placed in trenches and nearly covered with soil. They begin to sprout in about two weeks. When the cane is being grown for home consumption, the cuttings are often placed in holes. The crop has to be cultivated, weeded, and fertilized extensively during the first few months. It is harvested from 10 to 20 months after sprouting. Close watch is kept of the sugar content and the canes are cut at just the right stage. This is usually when the flowers are beginning to fade. The stems are cut close to the ground for the lower end of the cane is richest in sugar. Knives are ordinarily used, for machines have rarely proved practicable. The rhizomes will give rise to two or three more crops, known as *ratoons*, before another planting is necessary.

Formerly each small owner of a stand of sugar cane extracted his own sugar in a primitive mill, and even today these simple methods are followed in many places. In general, however, large "centrals" have been established which draw their supply from a wide area. The canes are brought to the centrals by railroad or any available means of transportation (Fig. 99). In the milling process the canes are first carried to crushers, where they are torn into small pieces. They are then passed through three sets of rollers. In the first set two-thirds of the juice is expressed.

They are then sprayed with water to dilute what sugar remains, and are passed through the second set. These rollers exert a tremendous pressure and remove nearly all the moisture. After passing through the last set the residue is almost bone dry. This *bagasse*, as it is called, can be used as a fuel for the mills, or as a source of paper or wallboard because of its fibrous nature.

The juice as it flows from the mill is a dark-grayish sweet liquid full of impurities. It contains sucrose, and other sugars as well,

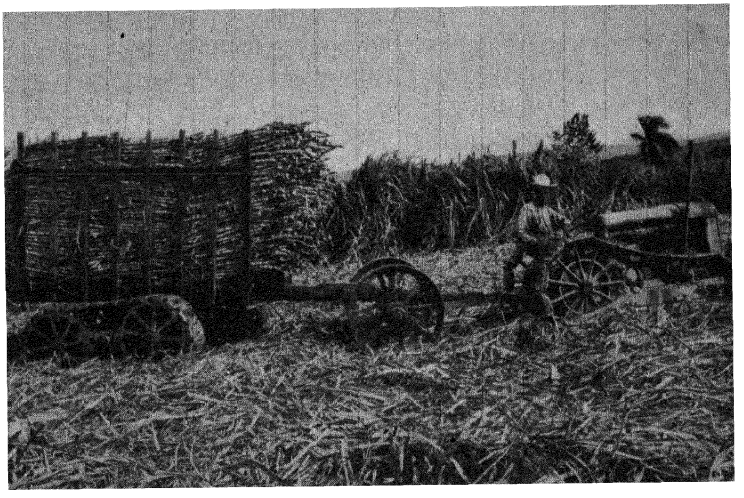


FIG. 99.—Hauling sugar cane from the field to the mill with a tractor. (*Courtesy of the United Fruit Company.*)

together with proteins, gums, acids, coloring materials, dirt, and pieces of cane. The purification of the sugar involves the separation of the insoluble materials (*defecation*) and the precipitation of the soluble nonsugars (*clarification*). The juice is first strained or filtered to remove the solid particles. It is then heated to coagulate the proteins, a process which the addition of sulphur assists. Next lime is added to neutralize the acids present, to prevent the conversion of sucrose into less desirable sugars, and to precipitate some of the substances in solution. These are removed by a series of filter bags or a filter press. Carbon dioxide is often added to aid in the process. The chemical processes involved in the purification of sugar are of great importance and are under constant supervision. The juice is now clear

and dark colored, and ready for concentration. It is boiled down to a syrup of such density that the sugar crystallizes out. This operation is carried on in open kettles or vacuum pans. The resulting sticky mass is known as *massecuite*. This is placed in hogsheads with perforated bottoms. The juice slowly percolates through the holes, leaving the crystals of sugar behind. This juice constitutes the familiar *molasses* of commerce. In many modern plants the massecuite is centrifuged, the molasses passing out through fine perforations. The raw or crude sugar thus obtained is brown in color and 96 per cent pure.

It can be seen that there are several by-products of value. The bagasse has already been mentioned. The molasses is a good foodstuff and is much used for cooking and candymaking. It is also used in the manufacture of rum and industrial alcohol. The better grades of molasses are obtained when the cruder methods of sugar milling are employed, for in such cases the sugar content of the molasses is higher. A mixture of bagasse and molasses, known as molascuit, is a valuable cattle food.

The final stage in the preparation of sugar for the market is the refining. This is usually carried on in factories located in the seaboard cities of the United States and Europe. The process involves washing to remove the film of dirt from around the crystals of crude sugar, dissolving the sugar in hot water, the removal of any mechanical impurities by filtering through cloth, decoloring by passing through bone black, recrystallization by boiling, and the removal of the liquids from the granulated sugar by centrifuging or other means. One hundred pounds of raw sugar yields 93 lb. of refined sugar and ¾ gal. of refined molasses. The granulated sugar is washed, dried, screened, and packed. Loaf, cube, and domino sugars are made by treating granulated sugar with a warm concentrated sugar solution and pressing it into molds. Loaf sugar is often sawed into blocks, strips, or other forms. Powdered sugar is made from loaf sugar or imperfect pieces of the other types by grinding, bolting, and mixing with starch to prevent lumping. The refining of sugar is a very old process and was probably derived from the Arabs. The first type of refined sugar was the sugar loaf, which was known in England as early as 1310 and was familiar in America until well into the last century.

In 1935–1936 India led in the production of cane sugar, raising about 33 per cent of the world's crop of 20,037,600 short tons. Cuba, Japan, Formosa, the Philippine Islands, Hawaii, Puerto Rico, Brazil, and Java followed in the order named. The United States mainland (Louisiana) produced 291,000 short tons. The United States leads the world in sugar consumption, averaging about 118 lb. per capita annually. Europe as a whole averages only 37 lb., although several countries may run as high as 80 or 90 lb.



FIG. 100.—A typical sugar beet (*Beta vulgaris*). (*Reproduced from U.S.D.A. Farmers' Bulletin* 1637, *Sugar Beet Culture in the Humid Area of the United States.*)

Sugar Beet

A second important source of sugar is the sugar beet, a variety of the common garden beet (*Beta vulgaris*) which was derived from the wild *Beta maritima*, a species still found on the seacoasts of Europe. The production of beet sugar has equalled, or even exceeded, that of cane sugar at various times. For the last 20 years, however, only about half as much beet sugar as cane sugar has been produced.

The sugar beet was known before the beginning of the Christian era, but was not used as a source of sugar until modern times. The presence of sugar in the roots was first noted in 1590, but Marcgraf in 1747 was the first to realize its possibilities. The first real impetus to the industry came about 1800 in both France and Germany. Napoleon backed it intensively as part of his embargo against British goods. He was subjected to much

ridicule because of this, and a famous cartoon was drawn picturing him dipping a sugar beet into his coffee; another showed him offering one to his little son, the King of Rome, with the caption, "Suck, dear, suck, your father says it's sugar." With the decline of Napoleon's power, interest in the crop waned. It was revived in France about 1829, and in Germany in 1835, and since that time has been a crop of steadily increasing importance in many European countries. Attempts were made to cultivate



FIG. 101.—Sugar-beet cultivation under irrigation. (*Courtesy of the U.S. Beet Sugar Association.*)

the sugar beet and manufacture beet sugar in the United States as early as 1836, but the industry has been successful only since 1879.

The sugar beet is a white-rooted biennial (Fig. 100) which grows best in regions where the summer temperature is around 70°F. The plant will grow in almost any good soil, and also in semiarid regions that can be irrigated (Fig. 101). The plants are grown from seed and must be thinned out until they are from 8 to 10 in. apart. Thorough weeding and deep cultivation are necessary. The crop lends itself readily to machine cultivation and harvesting, and so is much less expensive than sugar cane. The seeds are sown in April and the roots are kept in the ground until October for the sugar content increases as long as they are intact. Before the ground becomes too hard they are pulled, the

tops are removed (Fig. 102) to prevent any sugar utilization, and they are stored. The finest plants are saved for seed. The sugar beet has been greatly improved by selection.

Extraction of the juice is simpler than in the case of sugar cane, for the roots are soft and pulpy. Formerly they were rasped to a pulp and the juice squeezed out in bags, but at present a diffusion process is almost universally used. The roots are cleaned, cut into thin strips, and heated in running water in a series of



FIG. 102.—Harvesting sugar beets. (*Courtesy of the U.S. Beet Sugar Association.*)

tanks. Ninety seven per cent of the sugar can be extracted in this way. The waste beet pulp is removed, and the insoluble impurities in the raw juice are precipitated out by a process known as carbonation. In this process the raw juice is treated with lime, which coagulates some of the nonsugars, and carbon dioxide, which precipitates calcium carbonate. This settles out along with the impurities, and the purified juice is separated out by filtration. The process is repeated several times, during which sulphur dioxide is added to adjust the alkalinity. Filtration results in a clear liquid which is concentrated, crystallized, and centrifuged as in cane sugar. The massecuite is reboiled

several times. It is impossible to differentiate between raw beet sugar and raw cane sugar for they are identical in composition and appearance. By-products of the industry include the tops, which are used for cattle food and fertilizers; the wet or dried pulp, which is a valuable cattle and sheep food; the filter cake, which is used as a manure; and the molasses, which is used for stock feeding or for industrial alcohol.

Germany leads in the production of beet sugar with nearly 3,000,000 tons. Russia, Czechoslovakia, Poland, and France also grow large amounts. The output in the United States is about 1,100,000 tons, chiefly from Colorado, California, and Michigan.

Sugar Maple

The making of syrup and sugar from the sap of maple trees is confined to northeastern North America, and was discovered and developed in a crude way by the Indians. This was referred to by all the early explorers as far back as 1673. Many interesting legends exist regarding the first discovery of the sap by the Indians.

Several species of maple have a sweet sap. The most important of these are the sugar maple (*Acer saccharum*) and the black maple (*A. nigrum*). The sugar maple is a prominent tree in the northern part of the eastern deciduous forest region. It reproduces naturally and lives to an age of 300 or 400 years. The red and silver maples have such a small yield that they are of little use. The sap begins to flow about the middle of March and continues for a month or more. This is a period of warm, sunny days and cold nights. The best flow comes when the temperature reaches 25°F. at night and 55°F. during the day. The best location for tapping is the first 3 in. of sapwood, about 4½ ft. above the ground.

The Indians made incisions in the bark or large roots and conveyed the sap by reeds or curved pieces of bark into clay or bark receptacles. They boiled down the sap by dropping hot stones into it, and converted the sap into sugar by letting it freeze and skimming off the ice. The early settlers were quick to adopt the custom and they made many improvements, eventually tapping with a 1-in. auger and using spiles to convey the sap into containers. They evaporated the sap in the open in large

kettles so the sugar had many impurities. The dark-brown sap was stored and later converted into sugar. This involved the famous sugaring-off, a process in which the syrup was boiled until it became waxy and was then dropped into snow. It was then poured into molds, where it immediately crystallized. These simple methods are still in use for domestic purposes.

In commercial production further advances have been made and today modern evaporators have replaced the furnaces and



FIG. 103.—A maple-sugar orchard in Vermont. The sugar maple (*Acer saccharum*) trees have been tapped and pails put in place for collecting the sap. (*Photo by U.S. Forest Service.*)

boiling pans of earlier times. These are able to convert from 25 to 400 gal. of sap into syrup in 1 hour. Great improvements have also been made in cleanliness and in the methods of collecting and transporting the sap. These large operations involve from 100 to 1000 trees. A well managed sugarbush (Fig. 103) has about 70 trees to the acre, thus allowing plenty of room for the development of the individual trees.

The maple-sugar industry reached its peak in 1869 when 45,000,000 lb. were produced. With the advent of cane sugar it ceased to be an important commodity. Wholesale adulteration also tended to make it less popular. Today the product is much purer, and the demand is increasing. Vermont leads

in both sugar and syrup production, followed by New York and Ohio.

Palm Sugar

The juice of several species of palms constitutes a fourth source of commercial sugar. This, however, is available only in the tropics. The chief species utilized are the wild date (*Phoenix sylvestris*), the palmyra palm (*Borassus flabellifer*), the



FIG. 104.—Inflorescences of the coconut palm (*Cocos nucifera*) tapped and bamboo tubes in place for collecting the juice. (*Photo by Philippine Bureau of Forestry.*)

coconut (*Cocos nucifera*), the toddy palm (*Caryota urens*), and the gomuti palm (*Arenga pinnata*). Several of the oil palms also yield sugar. The date palm is tapped like a maple and the sap is obtained from the tender upper portions of the stem. In the other palms the sap is obtained from the unopened inflorescences. Usually the tip of these is cut off and the sap oozes out and is collected in various sorts of containers (Fig. 104). The yield of this sweet juice, which is known as toddy, amounts to 3 or 4 qt. a day for a period of several months. The sap has a sugar content of about 14 per cent. It is boiled down to a syrupy consistency and poured into leaves to cool and harden

into the crude sugar, known as jaggary. Some of this reaches European markets. Three quarts of juice yield 1 lb. of sugar. The toddy is often fermented to make the beverage known as arrack. The palm sugar industry is a very old one in India and over 100,000 tons are still produced each year. Palm sugar is also made in many other tropical countries.

Sorghum Syrup

The juice contained in the stem of the sweet sorghum (*Sorghum vulgare* var. *saccharatum*) is much used in making syrup. The difference between a true syrup and a molasses should be borne in mind. A syrup is the product obtained by merely evaporating the original juice of a plant, so that all the sugar is present. Molasses, on the other hand, is the residue left after a juice has been concentrated to a point where much of the sugar has crystallized out and been removed. The sweet sorghum or sorgo is a wild plant of the tropics and subtropics which has long been cultivated in many countries. The juice is a poor source of sugar, but yields a nutritious and wholesome syrup. The stems are easily crushed, and the juice is evaporated in shallow pans. About 13,000,000 gal. are made in the United States for cooking purposes. A similar syrup is now being made from sugar cane by clarifying the juice and evaporating it to a consistency where the water content is 25 to 30 per cent.

Other Sugars

Glucose.—Glucose, also known as dextrose or grape sugar, is the first sugar to be manufactured by the plant. It is present in small amounts in many of the organs of higher plants, and is particularly characteristic of fruits. For commercial purposes, however, glucose is prepared from starch, and it will be discussed in connection with starch products.

Fructose.—Fructose, sometimes called levulose or fruit sugar, is present in many fruits along with glucose. It is slightly sweeter than cane sugar, and is of value because it can be eaten by diabetics. Fructose is prepared commercially from inulin, a polysaccharide that occurs in the tubers of the dahlia (*Dahlia pinnata*), the Jerusalem artichoke (*Helianthus tuberosus*), and other plants. The latter species is now being cultivated quite extensively as a source of inulin.

Mannose.—Mannose does not occur free in nature, but is obtained by hydrolysis from several complex compounds. It is also readily oxidized from the juice of the manna ash (*Fraxinus Ornus*), a tree of Sicily and Southern Europe. This juice oozes from slits made in the bark and dries into a very sweet flakelike substance known as manna. Manna is used chiefly in medicine.

Maltose.—Maltose rarely occurs in a free condition in plants, but is readily produced from starch through the activity of the enzyme diastase. The chief use of maltose is in connection with the brewing industry, to be discussed later. Maltose syrup is sometimes used as a substitute for glucose and in medicine. The maltose obtained from rice starch has been used in Japan as a flavoring material for over two thousand years.

Honey

Most showy flowers secrete a sweet substance, known as nectar, which serves to attract the various insects essential for pollination. Nectar is composed chiefly of sucrose, with some fructose and glucose. It is used as food by bees, and some of it, after partial digestion, is converted into honey and stored up for future use. During this process the sucrose is changed into invert sugar, a mixture of fructose and glucose. Honey contains 70 to 75 per cent invert sugar, together with proteins, mineral salts, and water. Often the sugar tends to crystallize out. Honey was probably man's first sweetening material, and it has been used by him as a food for countless ages. Beekeeping is one of the oldest of industries. The flavor and quality of the honey vary, depending on the source of the nectar. Flowers that contain essential oils impart a characteristic taste. Although many plants are visited by bees, some are especially favored, and these are often cultivated near the apiaries. Alfalfa, clover, buckwheat, lindens, and several of the mints and citrus fruits are among the favorites. Honey is an excellent food for man, for it is almost pure sugar. It is also used in medicine, in the tobacco industry, and in the preparation of a fermented beverage called mead.

STARCHES AND STARCH PRODUCTS

Starch is one of the most important and widely occurring products of the vegetable kingdom, and constitutes the chief

type of reserve food for green plants. It is a complex carbohydrate. It is stored up in thin-walled cells in the form of grains. There are several types of starch differing in the size and shape

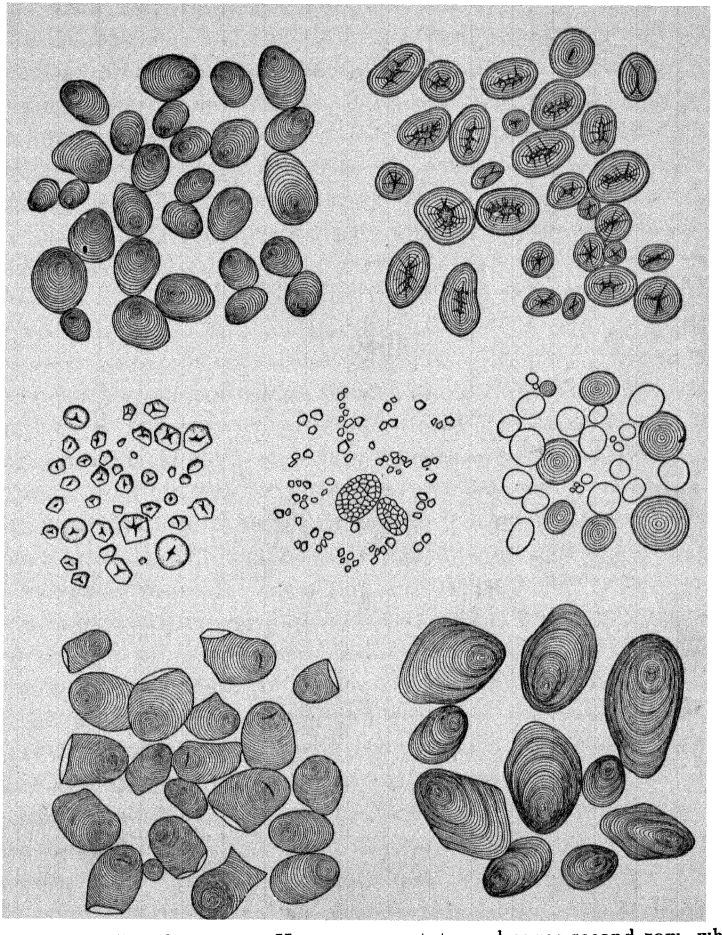


FIG. 105.—Starch grains. Upper row, potato and sago; second row, wheat, rice, and corn; third row, bean and West Indian arrowroot. (*Reproduced by permission from Brown, Textbook of General Botany, Ginn and Company.*)

of the grains and other physical and microscopic characteristics (Fig. 105). The most important sources of starch are the cereal grains and underground tubers, although legumes, nuts, and other plant organs may contain appreciable amounts. Although starch serves as the staple food for animals, and the greater portion of

mankind as well, it has so many industrial applications that it may well be considered at the present time.

Starch, in the form known as soluble starch, is extensively used in the textile industry to strengthen the fibers and cement the loose ends together, thus making a thread that is smoother and easier to weave. It also gives a finish to the goods. In calico printing it serves as a mordant, a thickener or vehicle for the colors. Starch is likewise used as a sizing agent in the paper industry, in laundry work, in medicine, in the preparation of toilet powders, as a binding material for china clay, and as a source of many derivatives or starch products.

Sources of Commercial Starch

Comparatively few starch-containing plants are used for the commercial production of starch, although the number is constantly increasing. The chief sources are maize, potato, wheat, rice, cassava, arrowroot, and sago.

Cornstarch.—The grains of maize or Indian corn constitute the source of five-sixths of the starch made in the United States. The grains are soaked in warm water with a little sulphurous acid to loosen the intercellular tissue and prevent fermentation. Then the corn is ground in such a way as not to injure the embryos. This ground material is placed in germ separators, where the embryos are removed. The starch material is then ground very fine and is either passed through sieves of bolting cloth or is washed in perforated cylinders in order to remove the bran. The resulting milky liquid is run onto slightly inclined tables, where the starch grains settle out and the remaining material flows off. The starch is later collected and dried in kilns, and is then ready for the market. The better grades of cornstarch are used for food; the inferior grades are used for laundry starch and sizing and as a basis for glucose. The United States produces over 400,000 tons of cornstarch.

Potato Starch.—Europe leads in the production of starch from potatoes with an output of 300,000 to 400,000 tons annually. In the United States about 30,000 tons are prepared, and some is imported. In this country the industry is carried on in many small factories located in the potato-raising states, chiefly in Maine and Wisconsin. The culls are utilized for starch. These are washed and reduced to a pulp in graters or rasping machines,

and the resulting paste is passed through sieves to remove all the fibrous matter. After washing, the solid starch is separated out by sedimentation, the use of inclined tables, or centrifuging, and is then dried. Potato starch is used in the textile industry and as a source of glucose, dextrin, and industrial alcohol.

Wheat Starch.—Wheat grains constitute the oldest of the commercial sources of starch. It was known to the Greeks, and was extensively used in Europe in the sixteenth century in connection with the linen industry. The presence of the gluten in wheat makes the removal of the starch a more difficult process. It is carried out by extraction with water or by the partial fermentation of the grain. Wheat starch is used almost exclusively in the textile industry.

Rice Starch.—Rice starch is obtained from broken or imperfect grains of rice. These are softened by treating with caustic soda, and are then washed, ground, and passed through fine sieves. More alkali is added and after a time the starch settles out as a sediment. This is removed, washed, and dried. Sometimes the starch grains are freed by treating with dilute hydrochloric acid. Rice starch is used for the most part in laundry work, and to some extent for sizing.

Cassava Starch.—The cassavas of tropical America are important sources of food and will be discussed later. Cassava flour and the more familiar tapioca, however, are also useful in the industries, particularly as sizing materials and as the source of many starch products.

Arrowroot Starch.—This starch is obtained from the tubers of several tropical plants. West Indian arrowroot comes from *Maranta arundinacea*, Florida arrowroot from *Zamia floridana*, Queensland arrowroot from *Canna edulis*, and East Indian arrowroot from *Curcuma angustifolia*. The tubers are peeled, washed, and crushed and the pulp is passed through perforated cylinders. A stream of water carries the starch into tanks where it settles out. Arrowroot starch is very easily digested and so is valuable as a food for children and invalids. It is but little used in the industries.

Sago Starch.—This starch is obtained from the stems of the sago palm (*Metroxylon Sagu*), a tall tree of the tropics (Fig. 106). It is cultivated in Malaya and the Dutch East Indies. The flowers appear when the trees are about 15 years of age, and just prior to this time the stems store up a large amount of starch.

The trees are cut down and the starchy pith is removed. This is ground up, mixed with water, and strained through a coarse sieve. The starch is freed from the water by sedimentation and, when washed and dried, is known as sago flour. The sago of



FIG. 100.—A plantation of sago palms (*Metroxylon Sagu*) in Singapore. (*Photo by E. H. Wilson; courtesy of the Arnold Arboretum.*)

commerce is prepared from this by making a paste and rubbing it through a sieve in order to bring about granulation. The product is dried in the sun or in ovens and appears as hard shiny grains, known as pearl sago. Both sago starch and pearl sago are used almost entirely for food purposes.

Starch Products

Soluble Starch.—Although starch grains are insoluble in cold water, they readily swell in hot water until they burst, and form

a thin, almost clear solution or paste. This soluble starch is much used for finishing textiles and in the paper industry.

Dextrin.—When starch is heated directly, or is treated with dilute acids or enzymes, it becomes converted into a tasteless, white, amorphous solid known as dextrin, or British gum. Because of their adhesive properties dextrins are frequently used as substitutes for mucilage, glue, and the natural gums. The United States now uses cornstarch dextrin on its postage stamps. Loaves of bread are painted with dextrin so a crust will form. In the steel industry the sand for the cores used in casting is held together with dextrin. Other uses are in cloth printing, glazing cards and paper, and making pasteboard.

Glucose.—If the process of treating starch with dilute acids is carried far enough, the starch is more completely hydrolyzed and is converted into glucose, a valuable sugar. In the United States glucose is made chiefly from cornstarch, and the product is often referred to as corn syrup. Often the same factory extracts the starch and then converts it into glucose. The operation is carried on in large copper boilers under pressure. About 6 lb. of dilute hydrochloric or sulphuric acid are used for each 10,000 lb. of starch. After all the starch has been converted, the free acids are neutralized with caustic soda. The liquid is then decolorized with boneblack and concentrated into a thick syrup. One of the common brands of corn syrup is "Karo." Glucose is often thought of as an inferior substitute for cane sugar. As a matter of fact, it is a real sugar in its own right and is a good food material. It is used as a table syrup, for sweetening, and in candies, jellies, and all kinds of cooking. It is often mixed with maple syrup, brown sugar, honey, or molasses. It is used for making vinegar and in brewing. The United States produces over 1,000,000 lb. annually. In Europe glucose is made chiefly from potato starch. Crystallized corn sugar or grape sugar can be prepared by continuing the hydrolysis of the starch to its completion, particularly if dilute sulphuric acid is used.

Industrial Alcohol.—An enormous quantity of industrial alcohol is manufactured from starch. Corn and potatoes constitute the chief sources, although the other starches, and even cellulose, the various products of the sugar industry, and fruit juices are utilized. The process involves the conversion of the starch into sugar by means of diastase and the fermentation of

the sugar by yeasts to yield the alcohol. The operations are carried out under different conditions from those followed in the manufacture of alcoholic beverages. After fermentation has stopped, the alcohol is extracted from the mash by fractional distillation. The alcohol thus formed as a result of the fermentation of sugar is known as ethyl alcohol, as distinguished from methyl or wood alcohol, a product of the destructive distillation of wood. In order to render it undrinkable, ethyl alcohol is often "denatured" by the addition of methyl alcohol or other substances. Industrial alcohol is the most important and most widely used solvent and is the basic material in the manufacture of several hundred products. It is also used in medicine, pharmacy, and various industries.

Nitrostarch.—Starch is so similar to cellulose in composition that it reacts in similar ways. Just as cellulose reacts with nitric acid to form nitrocellulose, so starch unites with this acid to yield nitrostarch. This is one of the safest of the high explosives, particularly if the ingredients are absolutely pure. Tapioca starch was formerly imported for this purpose, but during the World War the United States developed cornstarch as a source. By the end of the war 1,720,000 lb. of nitrostarch a month were being made for use in hand grenades.

CELLULOSE PRODUCTS

Cellulose, the most complex of the carbohydrates, is universally present in the cell walls of plants. Because of their strength, cells with thick walls have long been utilized in the industries. We have already discussed the usefulness of the various plant fibers in the textile and paper industries. Here, as in other cases, the natural products were the first to be used. Later the plants were cultivated, and during this period of cultivation it was possible to improve very considerably on nature. As a result of repeated experimentation, longer, stronger, and cheaper fibers were produced. Now we have reached a third stage in which we are no longer entirely dependent on natural products for our fibers, but are able to make them directly from cellulose. These synthetic fibers are only one example of the countless derivatives of cellulose, all of which are interesting and extremely valuable in our daily lives. Cellulose chemistry has become one of the most important phases of organic chemistry.

Artificial Fibers

From the Middle Ages until the present time there have been many schemes to make artificial silk and other fabrics. In 1880 Count de Chardonnet made the first synthetic fiber, and a few years later the first artificial silk. Shortly after, factories were established for making the product. At the outset this new material was handicapped by its name for the public considered it only as an imitation or a substitute. This condition existed as late as 1908. Now we realize that all the synthetic fibers constitute entirely new products with valuable characteristics and properties of their own. Today the production of these artificial fibers is one of the great industries. In the United States alone over 250,000,000 lb. were manufactured in 1935, a notable increase from the 800,000 lb. that constituted the first commercial production in 1911. At least four different processes are in use. In view of the fact, however, that about 85 per cent of the output is made by the viscose process and is marketed under the name "rayon," the Federal Trade Commission has decreed that all synthetic fibers should bear this name.

The raw material of the rayon industry is cellulose, prepared in a pure form from cotton linters or wood pulp. The first step in the manufacturing process is to dissolve the cellulose by means of various solvents, thus rendering it sufficiently liquid so that it can be squirted in a fine jet. The solution is then forced by pressure through minute perforations in glass or platinum, and emerges from these "spinnerets" in thin streams. These streams are coagulated into fine, almost invisible filaments in various ways. The solvents are removed, and the filaments are caught up by revolving reels and twisted into threads suitable for spinning. The threads are washed, bleached, and dried in skeins. In the viscose, nitrocellulose, and cuprammonium processes the final product is an almost pure cellulose fiber, known as *regenerated cellulose*. Chemically this is identical with the cellulose in cotton, but it differs in its mechanical properties. The product of the acetate process is a cellulose ester, *cellulose acetate*. This differs from regenerated cellulose in both its chemical and physical properties. The various kinds of rayon will be discussed briefly.

Viscose Rayon.—This is the original "rayon" process, and furnishes the greater part of the rayon manufactured. Bleached

sulphite wood pulp and pulp from cotton linters are used, often in equal amounts. The purified cellulose is treated with caustic soda and then with carbon bisulphide. The resulting cellulose xanthate, with the addition of a little water, becomes a foamy orange-yellow mass, known as viscose. This is allowed to age for a while and is then forced through the spinnerets into a regenerating solution. Here the xanthate groups are removed and the filaments of regenerated cellulose coagulate.

Cellulose Acetate Rayon.—This product is often called "celanese." Cotton or wood pulp is treated with acetic anhydride, acetic acid, and a little sulphuric acid as a catalyst. When dissolved, the material is poured into water and cellulose triacetate precipitates out. This is dissolved in acetone or other solvents and, when about the consistency of honey, it is forced through the spinnerets into a chamber containing warm air. Here the solvents evaporate and the cellulose acetate filaments coagulate. Acetate rayon is second to viscose rayon in importance.

Cuprammonium Rayon.—In this process the cellulose is treated with ammoniacal copper hydroxide. The viscous solution that results is forced through the spinnerets into an acid bath consisting of caustic soda or sulphuric acid, where the threads of regenerated cellulose coagulate.

Nitrocellulose Rayon.—This name is a misnomer, and the product should more properly be called cellulose nitrate rayon. It is often called Chardonnet silk, while the process is referred to as the Tubize process. Although it is the oldest type of rayon, only a small amount is made at the present time. Cotton linters are utilized. The cellulose is dissolved in nitric and sulphuric acids and the resulting pyroxylin is further dissolved in an ether-alcohol mixture or some other solvent. It is then forced through the perforations and coagulates in the air. The solvents are removed from the cellulose nitrate filaments, and also the nitro groups are removed in order to reduce the inflammability of the product, which is regenerated cellulose.

Rayon fibers are not quite so strong or elastic as natural fibers, but they have the sheen of silk and take dyes more readily. One handicap is their tendency to absorb a considerable amount of moisture when wet, and to weaken proportionately. They resume their strength, however, on drying out. Improvements

are constantly being made in the nature of the fibers. Acetate rayon does not absorb so much water and so is stronger in the presence of moisture. However, it does not take dyes so readily as the other types. Rayon is used alone or in combination with natural silk or other textile fibers. Such combinations may be dyed in two colors. Rayon is used for shirts, underwear, hosiery, braids, and many other goods. Men's hose is often "plated," consisting of rayon on the outside and cotton on the inside. The use of rayon is increasing.

Other Cellulose Products

The fact that cellulose will dissolve in various solvents has made possible the development of many other products of great value and usefulness. It will be possible to mention only a few of these cellulose derivatives.

Cellulose Nitrate Products

When cellulose is treated with concentrated nitric acid in the presence of sulphuric acid, several types of cellulose nitrate are formed. These differ depending on the concentration of the nitric acid, and the consequent degree of nitration; the temperature; and the duration of the action. The higher cellulose nitrates are called guncotton, or, erroneously, nitrocellulose. The lower nitrates constitute pyroxylin, or collodion cotton as it is sometimes called.

Guncotton is prepared from cotton linters, and during the process the cellulose is completely nitrated. It is used as an ingredient of many high explosives. Cordite, for example, is a combination of guncotton and nitroglycerin, while smokeless powder is made from a mixture of guncotton and the lower nitrates. When properly made, guncotton is one of the safest of the explosives to handle, particularly when it is wet.

Pyroxylin is produced by the partial nitration of cellulose. This process is carried on under different conditions from those which result in the formation of guncotton. The product is very valuable in industry. It made modern photography possible, for films usually consist of pyroxylin coated with gelatin. Its use in the rayon industry has already been mentioned. Perhaps the chief value of pyroxylin, however, lies in the fact that it is soluble in a variety of solvents and yields many

useful products, such as collodion, celluloid and other plastics, artificial fabrics, and varnishes.

Collodion is a solution of pyroxylin in a mixture of ether and alcohol. If a layer of collodion is spread out and exposed to the air, the solvents gradually evaporate and leave a thin, tough, impenetrable film. This characteristic makes collodion of value as a protective covering for wounds, and "New Skin" is familiar to everyone.

Celluloid is another well-known cellulose derivative. It consists of pyroxylin dissolved in camphor. Celluloid was first made in 1870 by John Hyatt. He mixed guncotton with camphor and placed the material in a hot press. The result was a clear homogeneous solid. At the present time celluloid can be easily made by nitrating thin tissue paper, or some other form of nearly pure cellulose, up to the point where the cellulose becomes soluble, but not far enough to convert it into guncotton. This pyroxylin is then mixed with camphor, submitted to pressure, and dried. Celluloid can be molded at 100°F. It can be dyed and made to imitate anything from ivory to coral and mosaics. Its chief drawback is its inflammability. Countless other products of a similar nature, such as pyralin, are on the market.

Artificial fabrics are now being made from cellulose nitrate. For many years oilcloth and linoleum were the only materials of this nature, and drying oils were necessary for their manufacture. Now modified cellulose nitrate is combined with various solvents, such as amyl acetate, butyl alcohol, etc., and many new and durable products are obtained. Among them may be mentioned the fabrics used for automobile curtains and cushions, and the leather substitutes, which can be used for shoes, bookbinding, and many other purposes.

The *varnish* industry has been revolutionized by the use of cellulose nitrate. The speed of modern automobile production required a varnish that would dry more quickly than those derived from the natural plant products. In answer to this demand the "lacquer paints," such as "Duco," were developed. Cottons linters are bleached and purified and converted into cellulose nitrate. This is mixed with small amounts of gums, resins, pigments, and various solvents. The resulting product yields in two days a finish more resistant and more durable than

the old varnishes formed in 24 days. These new varnishes are adapted to either wood or metal.

Cellulose Acetate Products

Cellulose acetate also has many important industrial uses. It is now extensively employed as a substitute for cellulose nitrate in the film industry for it is much less inflammable. However, the films are more brittle and more expensive. It is also used for automobile goggles, gas masks, automobile windows, coverings for index cards, artificial fabrics, varnish for airplane wings, and many other purposes.

Viscose Products

Viscose products are also of great importance. Perhaps the best known is *cellophane*, so extensively used for wrappings. This is made by forcing crude viscose through tiny slits rather than perforations. It coagulates into a thin transparent film $\frac{1}{1000}$ in. in thickness. These viscose films are now used for countless purposes, even for sausage casings. Viscose fibers have replaced cotton in Welsbach mantles.

Miscellaneous Products

Only a few of the many other cellulose derivatives and cellulose products can be mentioned. *Mercerized cotton* is made by treating cotton fibers with caustic soda. This gives a high luster and a silky appearance to the cotton. *Parchment paper* is prepared by dipping paper in strong sulphuric acid and then washing thoroughly. This treatment gives a hard, tough, translucent coating to the paper, which is waterproof and greaseproof. Paper made from cotton pulp can be *vulcanized* by treating it with a zinc chloride solution. It becomes hard and horny and can be used for trunks, boxes, and many mechanical purposes. It is now possible to convert the cellulose in sawdust into industrial alcohol, acetic acid, and even sugars, by various kinds of chemical and bacterial action. The possibilities for the future utilization of cellulose seem to be endless.

HEMICELLULOSE

The seeds of many tropical plants have exceedingly thick, hard, and heavy walls consisting of hemicellulose. This sub-

stance, which is a modification of normal cellulose, constitutes a supply of reserve food for the plant. In young seeds the endosperm consists of a milky juice, but as the seeds mature this fluid is gradually replaced by the horny material. Hemicellulose cannot be used by animals as a food. It does, however, play a

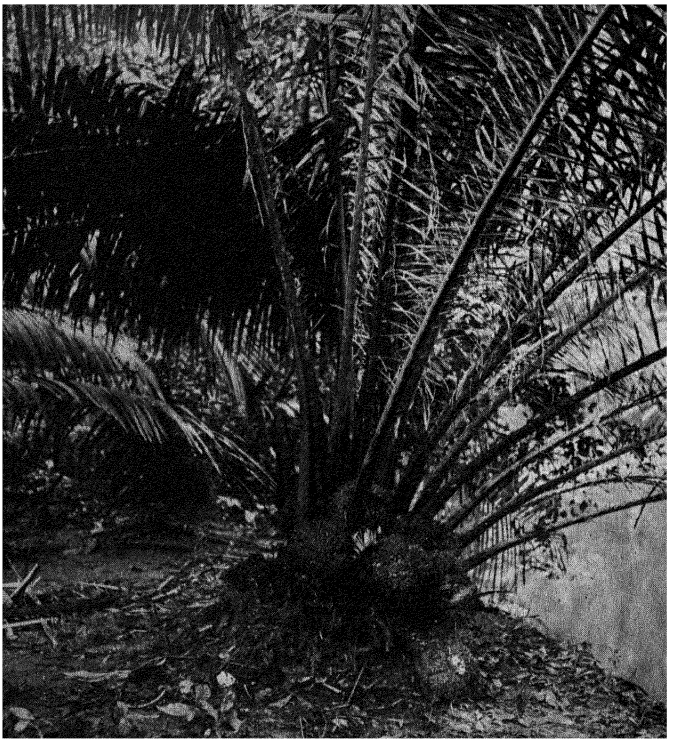


FIG. 107.—The ivory-nut palm (*Phytelephas macrocarpa*) in fruit. The seeds of this palm are the source of vegetable ivory.

part in the industrial world for it is the source of the vegetable ivory of commerce.

Vegetable Ivory

The chief source of vegetable ivory is the ivory nut or tagua palm (*Phytelephas macrocarpa*) of tropical America. This palm is a low-growing tree (Fig. 107) characteristic of river banks. The drupelike fruits contain from six to nine bony seeds with a

thin brown layer on the outside. Great numbers of these seeds are collected by the natives and shipped to Europe and the

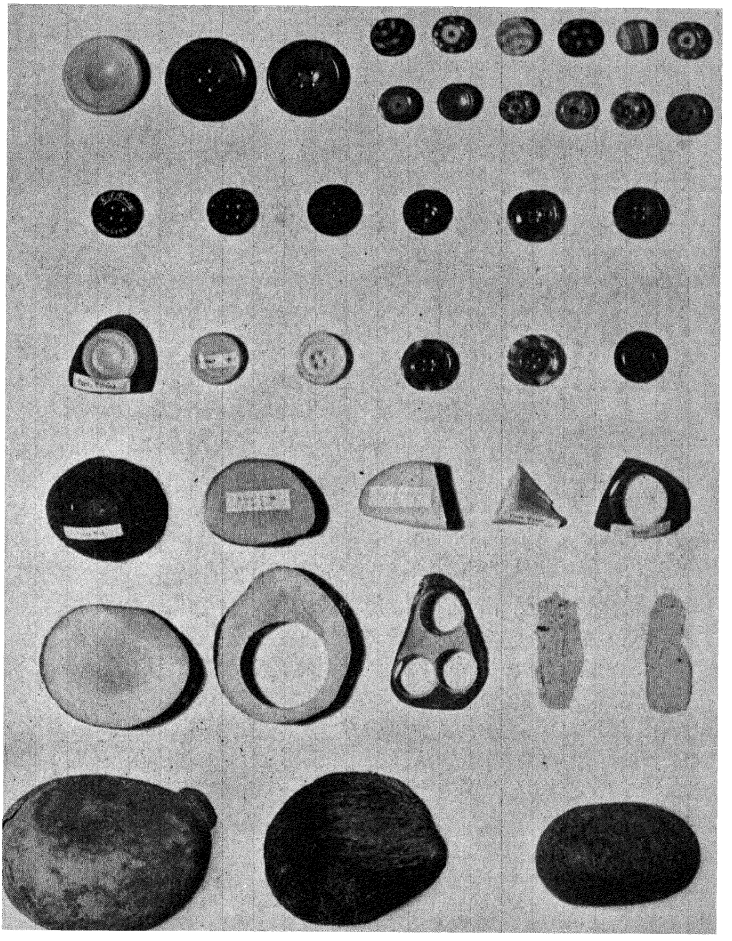


FIG. 108.—Stages in the manufacture of buttons from the seeds of the ivory-nut palm. (*Courtesy of the Botanical Museum of Harvard University.*)

United States. This vegetable ivory can be carved and turned and finds an extensive use as a substitute for true ivory in the manufacture of buttons (Fig. 108), chessmen, knobs, inlays, and similar articles.

Several African and Polynesian palms, as well as other tropical American species, have seeds of a somewhat similar nature. With the exception of *Coelococcus amicarum* of the Caroline Islands, however, these are not important articles of commerce.

1935 IMPORTS OF IMPORTANT SUGARS, STARCHES, AND HEMICELLULOSES

	Pounds		Pounds
Arrowroot starch and flour	4,511,846	Sago, crude	1,175,010
Cornstarch	640	Sago flour	23,631,003
Ivory nuts	12,200,462	Sugar, beet	1,681,598
Manna	46,402	Sugar, cane	5,908,294,819
Maple sugar	1,919,853	Tapioca and cassava, crude	1,934,440
Maple syrup	2,468,619	Tapioca, prepared	200,177,879
Potato starch	8,386,900	Wheat starch	132,271
Rice starch	359,046		

CHAPTER XI

MEDICINAL PLANTS

THE HISTORY OF MEDICINAL PLANTS

From earliest times mankind has used plants in an attempt to cure diseases and relieve physical suffering. Primitive peoples in all ages have had some knowledge of medicinal plants, derived as the result of trial and error. These primitive attempts at medicine were based on speculation and superstition. Most savage people have believed that disease was due to the presence of evil spirits in the body and could be driven out only by the use of poisonous or disagreeable substances calculated to make the body an unpleasant place in which to remain. The knowledge regarding the source and use of the various products suitable for this purpose was usually restricted to the medicine men of the tribe. As civilization progressed the early physicians were guided in great part by these observations.

In all the early civilizations there was much interest in drug plants. In China, as early as 5000 to 4000 B.C., many drugs were in use. There are Sanskrit writings in existence which tell of the methods of gathering and preparing drugs. The Assyrians, Babylonians, and ancient Hebrews were all familiar with their use. Some of the Egyptian papyri, written as early as 1600 B.C., record the names of many of the medicinal plants used by the physicians of that day, among them myrrh, cannabis, opium, aloes, hemlock, and cassia. The Greeks were familiar with many of the present-day drugs, as evidenced by the works of Aristotle, Hippocrates, Pythagoras, and Theophrastus. Even in their highly developed civilization, however, the supernatural element was still uppermost. Only a few men were considered able, because of some special power, to distinguish between valuable and harmful plants. These rhizotomoi, or root diggers, were an important caste in ancient Greece. The Romans were less interested in healing plants. However, in 77 B.C. Dioscorides wrote his great treatise, "De Materia Medica," which dealt

with the nature and properties of all the medicinal substances known at that time. For fifteen centuries this work was held in high esteem, and even today it is valued by the Moors and Turks. Pliny and Galen also wrote about drug plants.

After the Dark Ages were over, there came the period of the herbalists and encyclopedists, and the monasteries of Northern Europe produced vast compendiums of true and false information regarding plants, stressing in particular the medicinal value and folklore. It was about this time that the curious "Doctrine of Signatures" came into being. According to this superstitious doctrine all plants possessed some sign, given by the Creator, which indicated the use for which they were intended. Thus a plant with heart-shaped leaves should be used for heart ailments, the liverleaf with its three-lobed leaves for liver troubles, and so on. Many of the common names of our plants of today owe their origin to this curious belief. Such names as heartsease, Solomon's-seal, dogtooth violet and liverwort carry on the old superstition.

From this crude beginning the study of drugs and drug plants has progressed until now pharmacology is one of the essential branches of medicine. As an indication of the way botany and medicine have gone hand in hand, even in comparatively recent times, may be mentioned the fact that the great majority of the early botanists in the United States were also medical men.

DRUG PLANTS

For the purposes of economic botany we are most interested in that branch of pharmacology which deals with the drug plants. This is *pharmacognosy*, and it is concerned with the history, commerce, collection, selection, identification, and preservation of crude drugs and raw materials. Throughout the world several thousand plants have been and are still used for medicinal purposes. Many of these are known and utilized only by savage peoples, or by herb doctors and dwellers in primitive places who are forced to depend on the native plants of the vicinity.

The most valuable of the drugs and drug plants have been standardized as a result of the Pure Food and Drug Act of 1906. These are referred to as official drugs. Descriptions and other information regarding them are available in many places. The most important of these sources is the "United States

Pharmacopoeia." Similar pharmacopoeias are issued in most of the larger European countries. These works are constantly revised and kept up to date. The "National Formulary," published by the American Pharmaceutical Association, lists drugs of minor importance as well, but only those approved by law. The "Standard Dispensatory" and the "National Dispensatory" are other good reference works for all branches of materia medica.

Comparatively few drug plants are cultivated. Most of the supply of drugs is obtained from wild plants growing in all parts of the world, and especially in the tropics. These drug plants are collected and prepared in a crude way for shipment, and eventually reach the centers of the drug trade in this country and abroad. In some instances one country or another has built up a monopoly of some particular drug. Japan, for example, controls the output of camphor, while the Dutch in Java supply nearly all the quinine that enters the world trade. The United States is an important market for drug plants. From 1920 to 1930 the importation of crude drugs increased 140 per cent. In addition, several drugs are produced in this country, either from wild or cultivated sources. These include ginseng, goldenseal, cascara, digitalis, belladonna, hemp, wormseed, and stramonium.

The medicinal value of drug plants is due to the presence in the plant tissues of some chemical substance or substances that produce a definite physiological action on the human body. The most important of these substances are the alkaloids, compounds of carbon, hydrogen, oxygen, and nitrogen. Glucosides, essential oils, fatty oils, resins, mucilages, tannins, and gums are all utilized. Some of these materials are powerful poisons, so that the preparation and administering of the drugs should be left entirely in the hands of skilled pharmacists and physicians.

CLASSIFICATION OF DRUGS

The classification of drugs and drug plants is difficult for there are many methods of approach. The classification might be based on the chemical nature or the therapeutic value of the plant product, the natural affinities of the various species, or the morphology of the plant organ from which the drug is obtained. For our purposes it seems best to consider the more important drug plants on a morphological basis. In general, we find that

the active principles are present in the storage organs of the plants, particularly in roots and seeds, and to a lesser extent in leaves, bark, wood, or other parts of the plant. The total amount of the chemical substances present in any particular organ is so small that it is hard to ascribe any biological significance to it. There may be some slight protective function, but probably these principles, which are so valuable to man in the treatment of disease, are merely waste products of the metabolism of the plant.

Drugs Obtained from Roots and Other Underground Parts

Aconite.—Aconite is obtained from the roots of the monkshood (*Aconitum Napellus*). Although this familiar garden plant has long been known as a poison, its use in medicine is comparatively recent. The plant is a native of the Alps, Pyrenees, and other mountainous regions of Europe and Asia. It is widely cultivated in temperate countries both as an ornamental and as a drug plant. Formerly the leaves and flowering shoots were utilized, but at the present time only the roots are official. These are collected in the autumn and dried. Aconitine is the most important of the several alkaloids that are present. Aconite is used externally for neuralgia and rheumatism, and internally to relieve fever and pain.

Colchicum.—Colchicum root is the dried corm of *Colchicum autumnale*, a perennial herb of Europe and Northern Africa. The active principle is an alkaloid, which is used in the treatment of rheumatism and gout. The fresh roots are also used to some extent, and the seeds as well.

Gentian.—*Gentiana lutea*, a tall perennial herb with conspicuous orange-yellow flowers, is the source of gentian root or bitterroot. The plant is very common in the Alps and other mountains of Europe. The roots are dug in the fall, sliced, and dried. They contain several glucosides, which are valuable as a tonic for they can be used with iron salts.

Goldenseal.—Goldenseal (*Hydrastis canadensis*), formerly common in the rich woods of eastern North America, was a favorite remedy of the Indians and the early settlers. The plant is now extensively cultivated in the United States for it has almost been exterminated as a wild plant by drug collectors. The roots and rhizomes contain several alkaloids. Goldenseal

is used as a tonic and for the treatment of catarrh and other inflamed mucous membranes.

Ginseng.—Ginseng (Fig. 109) is one of the most important drugs in China, where it is considered to be a cure for a great variety of diseases. The true ginseng (*Panax Ginseng*), a plant of Eastern Asia, was at first the only source of the drug. The demand has been so great, however, that quantities of the American ginseng (*P. quinquefolium*) have been used in recent years. This plant of the eastern woodlands has been almost extermi-

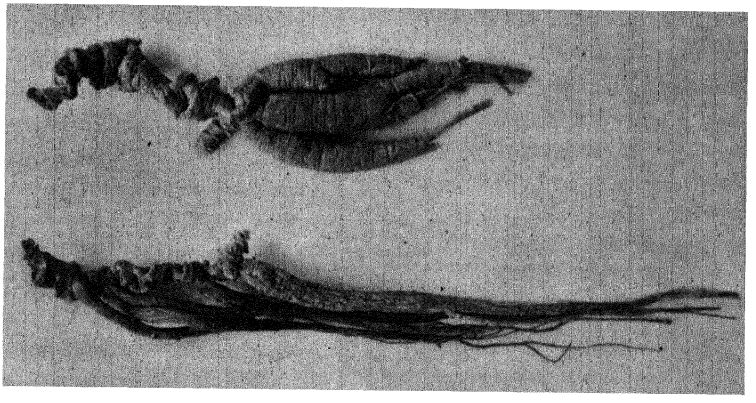


FIG. 109.—Ginseng roots (*Panax Ginseng*) from Manchuria.

nated by collectors and it is now being cultivated. Some ginseng is used in the United States as a stimulant and stomachic.

Ipecac.—A small shrub of the rich forests of Brazil and Colombia is the source of this well-known drug. Several species are used but the official material is the dried rhizome and roots of *Cephaelis Ipecacuanha.* The plant contains several alkaloids. Ipecac is used chiefly as an emetic and expectorant.

Jalap.—This drug is obtained from the tuberous roots of *Ipomoea Purga,* a twining vine of the rich woodlands of eastern Mexico. The plant is also cultivated in Jamaica and India. The roots are collected and dried over fires. The drug is used as a purgative. The active principle is a resin.

Licorice.—The licorice plant (*Glycyrrhiza glabra*) is a perennial herb that grows wild in Southern Europe and Western and Central Asia. It is also cultivated in many places within this area. Spain is the largest producer of cultivated licorice root.

The United States imports a large amount, chiefly from Asia Minor, Russia, and Turkey. The roots (Fig. 110, *C*) are dried in sheds for several months and are shipped in cylindrical pieces. Licorice is used in medicine as a demulcent and expectorant and to disguise the taste of nauseous preparations. Most of the supply, however, is used as a flavoring material in the tobacco and candy industries and in the manufacture of shoe polish. In recent years many other industrial uses have been found for this plant. It furnishes a compound, glycyrrhizin, which is fifty

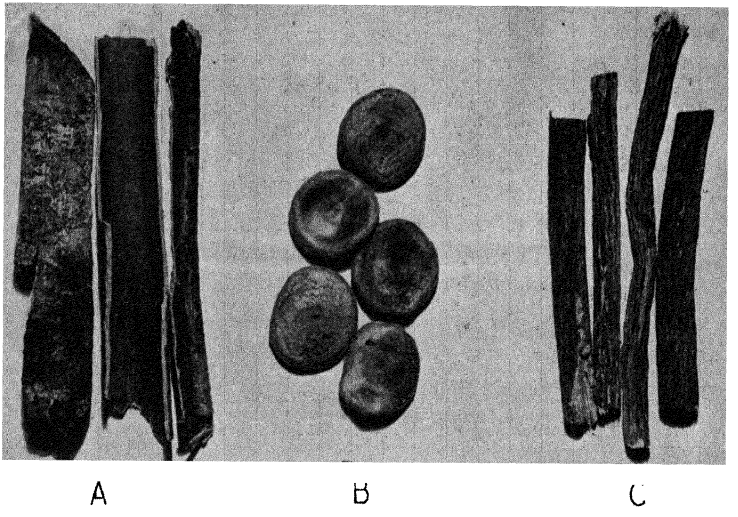


FIG. 110.—Three important crude drugs. *A*, cascara sagrada bark (*Rhamnus Purshiana*), *B*, nux vomica seeds (*Strychnos Nux-vomica*); *C*, licorice roots (*Glycyrrhiza glabra*).

times sweeter than sugar; a solution that is used for etching steel sections in photomicrographic work; and a substance from the waste root which foams readily and is used by brewers to give a head to beer. The fibers are utilized for wallboard and boxboard, under the name "Maftex"; for insulating materials; and for the Jacquard cards used for controlling the designs in the weaving of tapestries and other figured materials.

Podophyllum.—The roots and rhizomes of the mandrake or May apple (*Podophyllum peltatum*) yield the drug podophyllum, which has long been used by the country people of the eastern United States as an emetic and cathartic. The plant occurs throughout the Eastern states, but the commercial supply comes

from the southern Appalachians. The roots are collected in the fall or spring and are cut into cylindrical segments and carefully dried. They contain a resin, which is the source of the cathartic principles.

Rhubarb.—The source of the drug rhubarb is *Rheum officinale*, a native species of China and Tibet. This plant looks much like the garden rhubarb but grows to a greater size. It is extensively cultivated in China. The roots are dug and cut into short pieces or slices. These are threaded on a string and dried in the sun or in kilns. Rhubarb is used for indigestion and as a tonic and laxative.

Squills.—The sea onion or squills (*Urginea maritima*) is the source of this drug. The plant is a native of the sea coasts of the Mediterranean. The bulbs are dug up and the outer scales are removed. The fleshy inner scales are then sliced and dried Several glucosides are present. The drug is used as an expectorant and stimulant.

Marshmallow.—The dried roots of the marshmallow (*Althaea officinalis*) are the source of a nonpoisonous drug. The plant is a native of Eurasia, but is cultivated and naturalized in the United States. It is a perennial herb with very downy stems and leaves, and ornamental flowers. It grows in wet, swampy places, particularly salt marshes. The roots are collected in the fall of the second year and are scraped and dried. They contain a mucilaginous substance which has a soothing effect on inflamed tissues. It is used as a beverage or in pills and troches. The leaves are sometimes used as a poultice.

Scammony.—Scammony is obtained from the dried roots of *Convolvulus Scammonia*, a perennial twining vine of Southeastern Europe and Asia Minor. The active principle is a resin. It is a very old drug and was known to the Greeks, Romans, and Arabians. The drug was formerly obtained by removing the soil from around the roots and cutting off the top of the roots just below the crown. The resin exuded from this cut surface, which was renewed daily. The modern method is to extract the resin with alcohol from whole roots. Scammony is used chiefly as a purgative. The supply is rather limited.

Senega.—The senega snakeroot or milkwort (*Polygala Senega*), a small herbaceous perennial of eastern North America, is the source of a drug, which is obtained from the dried roots. Its

common name is derived from the fact that the Senega or Seneca Indians used the plant as a cure for snake bites. Senega is used as an expectorant, emetic, and stimulant.

Valerian.—The dried rhizome and roots of the garden heliotrope (*Valeriana officinalis*) are the source of this drug. This plant, a native of Eurasia, has long been cultivated in the United States as an ornamental species. The active principle is an essential oil which is used to relieve nervous afflictions, such as pain, coughing, and hysteria.

Drugs Obtained from Barks

Cascara.—This familiar drug is obtained from the bark of the western buckthorn (*Rhamnus Purshiana*), a tree of the northwestern United States and adjacent Canada. It was early used by the Western Indians, and by the pioneer Spanish settlers, who called it *cascara sagrada*, or sacred bark. For commercial purposes the bark (Fig. 110, *A*) is peeled off in long strips during the summer and dried on racks. It should be kept for a year before use. Cascara is a tonic and laxative. **Buckthorn** bark from *R. Frangula*, a European species, has similar properties.

Quinine.—Quinine is one of the most important drugs known and has been a great boon to mankind for it is the one and only cure for malaria. Several species of the genus *Cinchona* have a medicinal bark. The first to be utilized was *C. Calisaya*. The chief sources of commercial bark at the present time are *C. Ledgeriana*, *C. officinalis*, and *C. succiruba*. The cinchona trees are natives of the Andes of South America. They are evergreens with a hard, thick, grayish bark. Although known to the Indians previously, the first recorded use of the drug was in 1638, when it cured the Countess of Cinchon, wife of the Viceroy of Peru, of malaria after all other remedies had failed. The Jesuits carried cinchona with them all over the world and soon Peruvian bark or Jesuit's bark was in great demand. The supply seemed inexhaustible, but rapidly diminished under the wasteful methods of collection. The trees were cut down in order to strip off the bark, which was then dried in the open or over fires in huts. It soon became evident that attempts at cultivation must be made if this indispensable drug was to be available for future generations. Both the Dutch and the English sent collectors to South America, but the Andean natives

guarded the remnants of the cinchona forests most zealously. In spite of dangers and hardships, however, a few seedlings and seeds were finally smuggled out of the country and became the basis of the great cinchona plantations (Fig. 111) of today in Java and India. The bark is removed from the cultivated trees in the form of long quills. Most of the commercial supply comes from Java, as the Indian supply is used for home consump-



FIG. 111.—A cinchona plantation in Java. The bark of various species of *Cinchona* is the source of quinine.

tion. The bark contains several alkaloids, the most important of which is quinine, a very bitter substance. In addition to its use in the treatment of malaria, quinine is valuable as a tonic and antiseptic and for use in the treatment of fevers generally.

Slippery Elm.—The inner bark of the slippery elm (*Ulmus fulva*), a large tree of eastern North America, is the source of this nonpoisonous drug. The bark is removed in the spring and the outer layers are discarded, while the inner portion is dried. Slippery elm bark has a very characteristic odor. It contains mucilage and is used for its soothing effect on inflamed tissues, either in the crude state or in the form of lozenges.

Drugs Obtained from Woods

Ephedrine.—Ephedrine is an alkaloid that is obtained from *Ephedra sinica*, *E. equisetina*, and other Asiatic species of the genus. These plants are low, dioecious, leafless shrubs with slender green stems (Fig. 112). The entire woody plant is used for the extraction of the drug. Under the name "ma huang,"



FIG. 112.—*Ephedra equisetina* (left and center) and *E. sinica* (right). These low leafless shrubs are the source of the drug ephedrine. (*Reproduced by permission from Youngken, Textbook of Pharmacognosy, P. Blakiston's Son & Company.*)

ephedra has been used in China for over five thousand years. In the United States ephedrine has been used extensively in recent years in the treatment of colds and for other medicinal purposes.

Guaiacum.—Guaiacum or gum guaiac is a hard resin that exudes naturally from the stems of the lignum vitae trees (*Guaiacum officinale* and *G. sanctum*), previously discussed. It hardens as round, glassy, greenish-brown tears. It is also obtained from

incisions, from the cut ends of logs, or from pieces of the wood. Gum guaiac is used as a stimulant and laxative. It is also a good chemical indicator as it is very sensitive to oxygen. The lignum vitae trees are evergreens native to the West Indies and South America.

Quassia.—Quassia is obtained from two different sources. Jamaican quassia comes from *Picraena excelsa*, a tall tree of Jamaica and other West Indian islands, while Surinam quassia is the product of *Quassia amara*, which grows in tropical America as well as in the West Indies. The latter species is a valuable timber tree with a lustrous, yellowish-white, fine-grained wood. Quassia is shipped in the form of billets, and the drug is prepared by making an effusion of chips or shavings. It has a very bitter taste and is used as a tonic and in the treatment of dyspepsia and malaria. It also serves as an insecticide.

The medicinal use of balsams and other oleoresinous exudations from trees has already been discussed in Chap. VII.

Drugs Obtained from Leaves

Aloe.—Several kinds of aloes are on the market. Barbadoes aloes come from *Aloe vulgaris* of the West Indies, Socotrine aloes from *A. Perryi* of West Africa, and Cape aloes from *A. ferox* of South Africa. Aloes are tropical plants with succulent leaves and showy flowers. They are frequently cultivated in greenhouses. The leaves contain a resinous juice in which there are several glucosides. If the leaves are cut and placed in troughs, the juice slowly exudes and can be collected. It is evaporated in pans to a thick, viscous black mass, which may be solidified. Aloes are used chiefly as purgatives.

Belladonna.—This important drug is obtained from the dried leaves and tops, and to some extent the roots, of *Atropa Belladonna* (Fig. 113). This plant is a coarse herb, native to Central and Southern Europe and Asia Minor. It is extensively cultivated as a drug plant in the United States, Europe, and India. The leaves are collected during the flowering season and dried. They contain several alkaloids, chief among which are hyoscyamine and atropine. Belladonna is used externally to relieve pain and internally to check excessive perspiration, coughs, etc. Atropine is used to dilate the pupil of the eye.

Cocaine.—The leaves of the coca shrub (*Erythroxylon Coca*), a native of Peru and Bolivia, furnish this drug. The plant is extensively cultivated in South America, where the leaves are used as a masticatory, and also in Java and Formosa. The leaves mature in about four years and can then be picked three

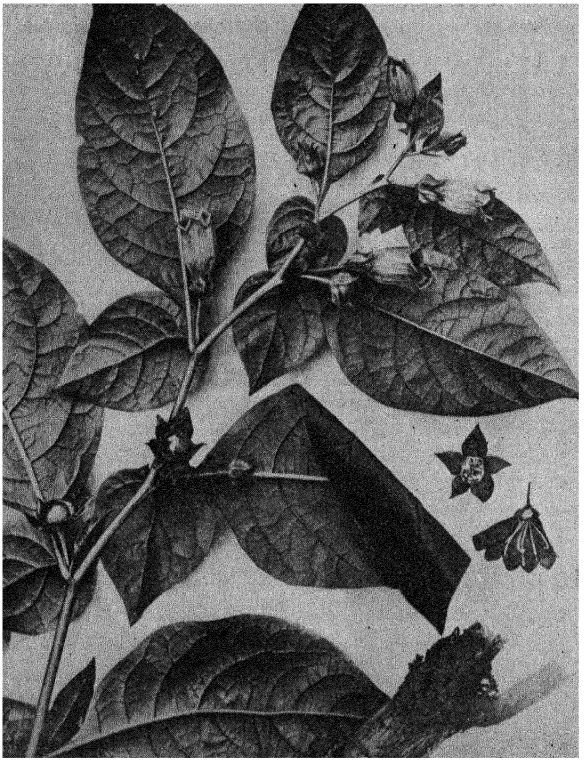


FIG. 113.—The belladonna plant (*Atropa Belladonna*). The dried leaves and tops, and to some extent the roots, are the source of the drugs belladonna and atropine.

or four times a year. They are carefully dried and shipped in bales. They have a bitter aromatic taste due to the presence of the alkaloid cocaine. It takes 100 lb. of leaves to yield 1 lb. of the drug. Cocaine has been much used as a local anesthetic. It is also employed as a tonic for the digestive and nervous systems, but as it is a habit-forming drug its use should be supervised by physicians.

Buchu.—This drug is obtained from the dried leaves of *Barosma betulina*, *B. serratifolia*, and *B. crenulata*, shrubs of the hot dry mountainous regions of South Africa. The active principle is an essential oil. Buchu is used as a disinfectant and to stimulate excretion, and also in the treatment of indigestion.

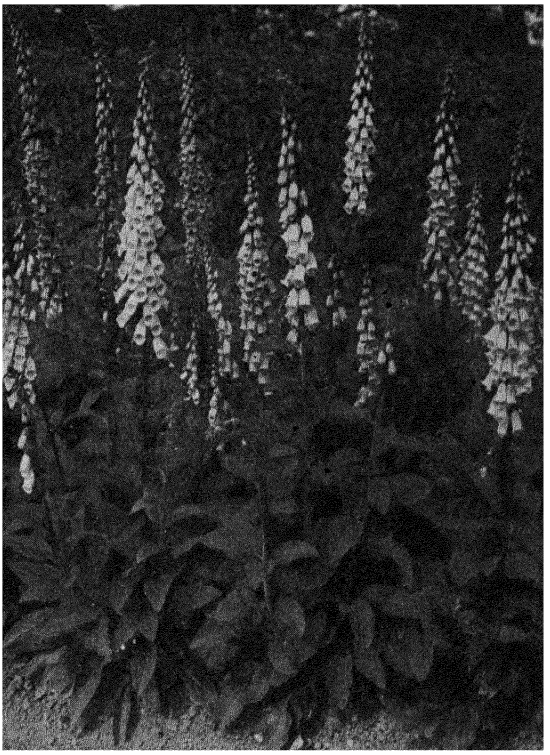


FIG. 114.—Foxglove plants (*Digitalis purpurea*). The important drug digitalis is obtained from the dried leaves of this plant. (*Courtesy of Breck and Company.*)

Cajeput.—The fresh leaves of *Melaleuca Leucadendron*, a small tree of Southeastern Asia, yield an essential oil that is a universal remedy in the East. The greenish oil is aromatic with a camphorlike odor. It is used as a counterirritant and antiseptic in the treatment of skin diseases, rheumatism, and bronchitis. Cajeput is more extensively used in Europe than in the United States.

Digitalis.—This drug, almost indispensable in the treatment of heart disorders, is obtained from the dried leaves of the foxglove (*Digitalis purpurea*), a native of Southern and Central Europe. The plant is a beautiful herbaceous perennial (Fig. 114) with tufted basal leaves and a single, erect, leafy stem which bears a spike of purplish flowers. The foxglove is frequently grown for ornamental purposes, as well as for the drug. Fresh and full-grown leaves are carefully and quickly dried for use as the source of the drug. The medicinal properties of digitalis have been known for a long time. The most active principle is a glucoside, digitoxin. Digitalis is a heart stimulant of the greatest importance because of its powerful action, and it is specific for some types of heart disease. It improves the tone and rhythm of the heart beats, making the contractions more powerful and complete. Consequently more blood is sent out from the heart, thus aiding the circulation, improving the nutrition of the body, and hastening the elimination of waste.

Eucalyptus.—The scythe-shaped leaves of the older growth of the blue gum (*Eucalyptus globulus*) contain an essential oil that is widely used in medicine. The tree, which is one of the tallest known, reaching a height of from 200 to 300 ft., is a native of Australia. It is extensively cultivated in California (Fig. 115), Florida, and the Mediterranean region. It is commonly supposed that eucalyptus trees aid in ridding a country of malaria. Because of their great height and extensive root system it is assumed that they must remove great quantities of water from the soil, thus tending to dry out mosquito-infested areas. Eucalyptus oil, obtained from dried leaves, is used chiefly in the treatment of nose and throat disorders, malaria, and other fevers. The oil is colorless or pale yellow, spicy, and pungent.

Hamamelis.—The common witch hazel (*Hamamelis virginiana*), a shrub of eastern North America, is the source of this product. The official source is the dried leaves and the commercial supply of these comes chiefly from the southern Appalachians. In New England, however, and elsewhere, the bark, twigs, and sometimes the entire plant are utilized. The active principle is extracted with water and steam and distilled. After 150 cc. of alcohol have been added to each 850 cc. of the distillate, the familiar witch hazel or hamamelis extract is obtained. This is used as an astringent and to stop bleeding.

Henbane.—Henbane (*Hyoscyamus niger*), a coarse evil-smelling herb, is a native of Europe and Asia, but grows as a weed in many other parts of the world. Its leaves and flowering tops contain several poisonous alkaloids. The plant is cultivated for the drugs, which are used as sedatives.

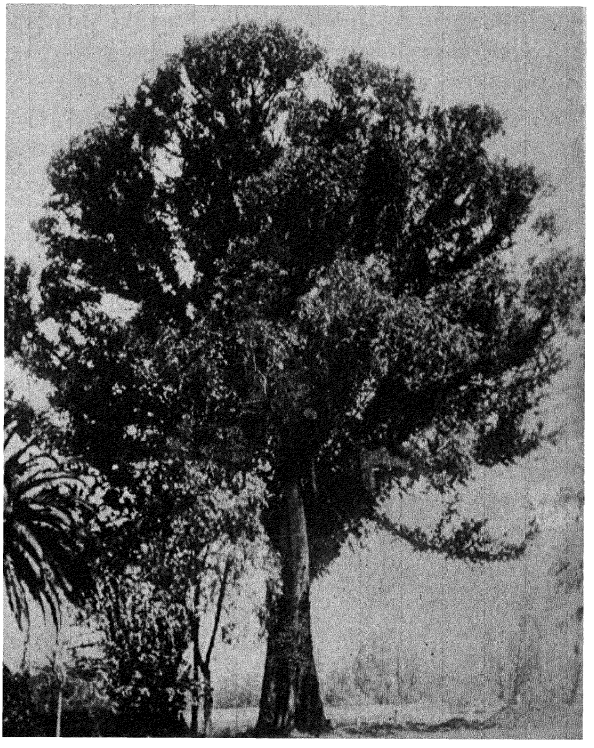


FIG. 115.—The blue gum (*Eucalyptus globulus*), an Australian tree, is extensively planted in California. "The Joseph Aram Blue Gum," pictured here, was probably set out in the 1860's. It is about 105 ft. tall and has a diameter of 95 in. at breast height. Oil of eucalyptus is obtained from the leaves of the blue gum. (*Photo by U.S. Forest Service.*)

Hoarhound.—The hoarhound (*Marrubium vulgare*) is a native of Europe and Central Asia, but is thoroughly naturalized in America. It is a small herbaceous perennial with white flowers in dense axillary whorls. The dried leaves and flowering tops are used medicinally. Hoarhound is administered as an infusion or in the form of candy or lozenges. It is a favorite domestic

remedy for breaking up colds, and is also used for rheumatism, dyspepsia, and other ailments.

Lobelia.—This drug is obtained from the dried leaves and tops of the Indian tobacco (*Lobelia inflata*), a small annual with numerous blue flowers in leafy terminal racemes. The plant is a native of North America and is one of our comparatively few poisonous species. The active principle is an alkaloid. Lobelia is used as an expectorant, antispasmodic, and emetic. It was also used by the American Indians.

Pennyroyal.—Pennyroyal (*Hedeoma pulegioides*) is a small aromatic annual common in poor soil throughout the eastern United States. It contains an essential oil that has some use in internal medicine. Pennyroyal is often used as an ingredient of liniments because of its counterirritant action. Its chief use, however, is as an insect repellent. The oil is obtained commercially from the dried leaves and tops.

Senna.—This drug is obtained from the dried leaflets, and also the pods, of several species of *Cassia*, which are indigenous to the arid regions of Egypt and Arabia. Alexandrian senna comes from *C. acutifolia* and Indian senna from *C. angustifolia*. Wild plants of the first of these species are still used as a source of the drug in Egypt. Both of them are cultivated in India. The leaves are picked by the natives, dried in the sun, and baled. Senna is used as a cathartic.

Stramonium.—The Jimson weed or thorn apple (*Datura Stramonium*), one of the most poisonous of plants, is the source of this drug. The plant is a native of Asia, but occurs as a weed in fields and waste places all over the world. It is a coarse, rank annual growing to a height of 4 ft. It is cultivated in the United States and Europe for the alkaloid stramonium, which is extracted from the dried leaves and flowering tops. This drug is used as a substitute for belladonna for relaxing the bronchial muscles in the treatment of asthma. In many parts of the world stramonium is used for its narcotic effects.

Wormwood.—The wormwood (*Artemisia Absinthium*), a native of Europe, Northern Africa, and Northern Asia, is the source of an essential oil used somewhat in medicine. The dried leaves and tops of the plant are steeped in alcohol and distilled. The resulting greenish liquid is used to some extent in the treatment of fevers, but it is no longer official. Worm-

wood is extremely deleterious when taken in quantity. The chief use of the essential oil is to flavor the liqueur known as absinthe, the use of which is forbidden in many countries. Absinthe contains other aromatics as well as wormwood.

Drugs Obtained from Flowers

Chamomile.—Chamomile is an old-time remedy obtained from *Matricaria Chamomilla.* This daisylike plant, a native of Eurasia, is cultivated in the United States and elsewhere. The dried flower heads contain an essential oil. Infusions of chamomile are used as tonics and gastric stimulants. The flower heads of the Russian or garden chamomile (*Anthemis nobilis*) are used for similar purposes, and also in poultices for sprains, bruises, and rheumatism.



FIG. 116 —Growing hops (*Humulus Lupulus*) on poles in Canterbury, England.

Hops.—The hop (*Humulus Lupulus*) is a native of the north temperate regions of both hemispheres. The plant was known to the Romans and has been grown in some parts of Europe since the ninth century. At the present time hops are extensively cultivated in the United States, England, and Germany. The plant is a climbing herb with perennial roots. These send up annually several rough, weak, angular stems with deeply-lobed leaves and dioecious flowers. The female flowers are produced

in scaly, conelike catkins, which are covered with glandular hairs. These inflorescences contain resin and various bitter, aromatic, and narcotic principles, chief of which is lupulin. In cultivation the hop plants are trained on poles (Fig. 116) or trellises. Hops are harvested in the early fall. The catkins are carefully picked and dried in kilns at a temperature of 70°F. or less. They are treated with sulphur and baled for shipment. Hops are used in medicine for their sedative and soporific properties, and also as a tonic. Sometimes they are used in poultices. Their principal use, however, is in the brewing industry. They are added to beer to prevent bacterial action and consequent decomposition, and also to improve the flavor and impart the characteristic bitter taste to the beverage.

Santonin.—The dried unopened flower heads of the Levant wormseed (*Artemisia Cina*) contain a valuable drug known as santonin. The plant is a small semishrubby perennial of Western Asia. The present supply of the drug comes chiefly from Turkestan, although this species is now being grown experimentally in the United States. Formerly the crude drug was shipped, but now the santonin is extracted and exported. This drug is one of the best remedies for intestinal worms, and has been used for this purpose for centuries. It was introduced into Europe by the Crusaders.

Drugs Obtained from Fruits and Seeds

Chaulmoogra Oil.—For centuries leprosy has been one of the most dreaded diseases of mankind and it was long thought to be incurable. It was known, however, that the natives of Burma and other parts of Southeastern Asia used the seeds and oil obtained from the chaulmoogra tree (*Hydnocarpus Kurzii*) and related species in the treatment of skin diseases. These tall trees of the dense jungles have velvety fruits (Fig. 117) with several large seeds, which contain a fatty oil with a characteristic odor and acrid taste. The expressed oil is a brownish-yellow liquid or soft solid. Experiments have been carried on at the University of Hawaii in an attempt to use this oil in the development of a successful treatment for leprosy. The crude oil proved unsatisfactory and, moreover, the treatment was very painful. The use of certain acids present in the oil, or of the ethyl esters

of these acids, was productive of the desired results, and leprosy can now be cured.

Colocynth.—The dried spongy pulp of the bitter apple (*Citrullus Colocynthis*) is the source of the drug colocynth. The plant is a perennial vine native to the warmer parts of Asia and Africa. It is now widely distributed, and is cultivated in the Mediterranean region. The fruits resemble oranges in appearance.

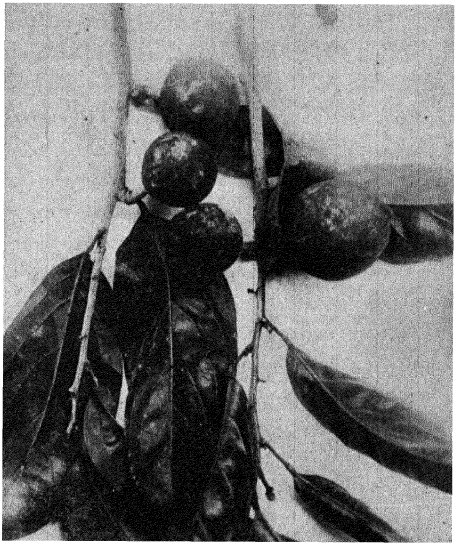


FIG. 117.—A fruiting branch of the chaulmoogra tree (*Hydnocarpus Kurzii*). Chaulmoogra oil, which is obtained from the seeds, is used in the treatment of leprosy.

The rind is removed and the white bitter pulp is dried and shipped in balls. Colocynth serves as a powerful purgative.

Cubebs.—Cubebs are the dried unripe fruits of *Piper Cubeba*, a climbing vine of eastern India and Malaya. It is cultivated in Java, Siam, Ceylon, and the West Indies. The berries resemble black pepper, but are stalked. They have a warm, bitter, aromatic taste and a strong odor, due to the presence of an essential oil. Cubebs are used in the treatment of catarrh, often in the form of cigarettes, and as a kidney stimulant. They were formerly used as a spice or condiment.

Croton Oil.—Croton oil is a fatty oil obtained from the dried ripe seeds of *Croton Tiglium*, a shrub or small tree of South-

eastern Asia. It is cultivated in India and Ceylon. Croton oil is a yellowish-brown liquid with a burning taste and nauseous odor. It is one of the most powerful purgatives known. The flowers and crushed leaves are used in India to poison fishes.

Nux Vomica.—This valuable drug is obtained from the seeds of *Strychnos Nux-vomica*, a tree native to Ceylon, India, Cochin China, and Australia. The large fruits contain from three to five grayish seeds (Fig. 110, *B*) which are very hard and bitter. Ripe seeds contain two important alkaloids, strychnine and bucine. The former is used as a tonic and in the treatment of nervous disorders and paralysis, always in small doses, for it is a virulent poison. The use of this drug dates back to the sixteenth century.

Opium.—Opium, one of the most helpful, and at the same time vicious, drugs, is the dried juice or latex obtained from the unripe capsules of the opium poppy (*Papaver somniferum*). This poppy is an annual herb with large showy white flowers. A native of Western Asia, it now occurs in most countries as a weed. It is cultivated extensively in India, China (Fig. 125), and elsewhere. Shortly after the petals fall the capsules are incised with a knife, and the white latex exudes and soon hardens in the air. It is scraped off and shaped into balls or cakes, which are often wrapped in the poppy petals. Crude opium is a brownish material containing as many as 20 alkaloids, the most important of which are morphine and codeine. In medicine opium and its derivatives are used to relieve pain, induce sleep, and relax spasms. They should never be administered except under a physician's direction. Because of the flagrant misuse of the drug and its deleterious effects physically, mentally, and morally, the opium trade is very carefully supervised and restricted.

Psyllium.—The drug known as psyllium has changed from a position of obscurity to one of foremost importance within the last few years. Although used locally in Europe for 50 years or more, it has only recently entered the drug markets. Psyllium is the seed of the fleawort (*Plantago Psyllium*), a European species of plantain. It is now cultivated in France and Spain. Two crops are raised each year with a yield of 7000 to 8000 lb. per acre. Psyllium seed constitutes a tasteless mild laxative, and is comparable to agar and mineral oil.

Strophanthus.—The dried, greenish, ripe seeds of *Strophanthus Kombe* and *S. hispidus*, woody climbers of the African forests, are

the source of the drug strophanthus, which is used as a heart stimulant. It has a direct and powerful action. The active principles are alkaloidal in nature.

Wormseed.—The American wormseed (*Chenopodium ambrosioides* var. *anthelminticum*) is a native of the West Indies and Central and South America. It is naturalized in the United States, occurring as a weed in waste places. It is also extensively cultivated for its essential oil, which is obtained from the seeds, and also the entire leafy part of the plant. This drug is used for expelling worms.

Drugs Obtained from the Lower Plants

Agar.—Agar is an almost pure mucilage obtained from *Gelidium corneum*, *Eucheuma spinosum*, *Gracilaria lichenoides*, and other seaweeds found off the eastern and southern coasts of Asia. The algae are collected, bleached, and dried during the summer and autumn. Later on the mucilaginous material is extracted with water. Agar reaches the markets in strips which are brittle when dry, but which become tough and resistant when moist. It finds its greatest use as a culture medium for bacteria and other fungi. Its medicinal value lies in its absorptive and lubricating action. It is often used in a granular condition to prevent constipation. In the Orient agar is used in soups and custards and in the paper and silk industries.

Ergot.—Ergot is the fruiting body of a fungus, *Claviceps purpurea*, which is parasitic on rye and other grasses. The disease attacks the young fruit and, when mature, a purplish structure, the sclerotium, replaces the grain. Commercial ergot comes chiefly from Europe where it is picked from the rye plants by hand or, after the rye has been threshed, by special machinery. Ergot is of value in medicine by increasing the blood pressure. It is used in cases of hemorrhages and uterine disturbances.

Kelp.—In Japan and several Northern European countries various of the larger brown algae have long been used as a source of iodine, potash, and other salts. More recently a considerable industry has been built up on the west coast of the United States for the extraction of iodine and potash from the giant kelps of the Pacific, particularly *Macrocystis pyrifera*. Within the last few years attention has been directed to the medicinal value of these seaweeds. Several products are now on the market which

make available the surprising wealth of mineral salts and vitamins that these plants contain. Salts of aluminum, calcium, chlorine, copper, iodine, iron, magnesium, manganese, phosphorus, potassium, sodium, sulphur, and zinc are present, together with larger or smaller amounts of the various vitamins that occur in plants.

Male Fern.—The rhizomes and stalks of the male fern (*Dryopteris Filix-mas*) contain an oleoresin that has been used for centuries for expelling worms. This fern is a native of Asia, Europe, and northern North America, but the supply of the drug comes from Europe.

INSECTICIDES

Plants have been used for insecticidal purposes for many years in various parts of the world. In the United States over 250 species have been utilized for this purpose. Only 5 per cent of these plants, however, are of any commercial value. In recent years the botanical insecticides have increased greatly in importance, particularly in this country, and the United States is today the leading market of the world for these products. Pyrethrum flowers are the most important source of insecticides, but derris and cubé are rapidly gaining recognition.

Pyrethrum

Three principal sources of pyrethrum or insect flowers are recognized in the United States. Of these the *Dalmatian insect flowers* (*Chrysanthemum cinerariaefolium*) are the most important. This species is a slender, glaucous, pubescent perennial, 1 to 1½ ft. in height, with pinnate leaves and small daisylike flowers. It is a native of Dalmatia in Jugoslavia, where it has been cultivated for many years. At the present time, however, Japan is the leading producer of Dalmatian insect flowers. As a result of advanced methods of production and trade this product has become one of Japan's most valuable exports. Great care is exercised in gathering, drying, and packing the crop. This species is now being cultivated in California and other parts of the United States.

Persian insect flowers are obtained from *Chrysanthemum coccineum*, a native of Southwestern Asia, which has flowers of

various colors; *Caucasian insect flowers* come for *C. Marschallii*, a red-flowered species.

Derris

Derris or tuba roots (Fig. 118) have long been used by the natives of Malaya and Borneo for fish and arrowhead poisons.

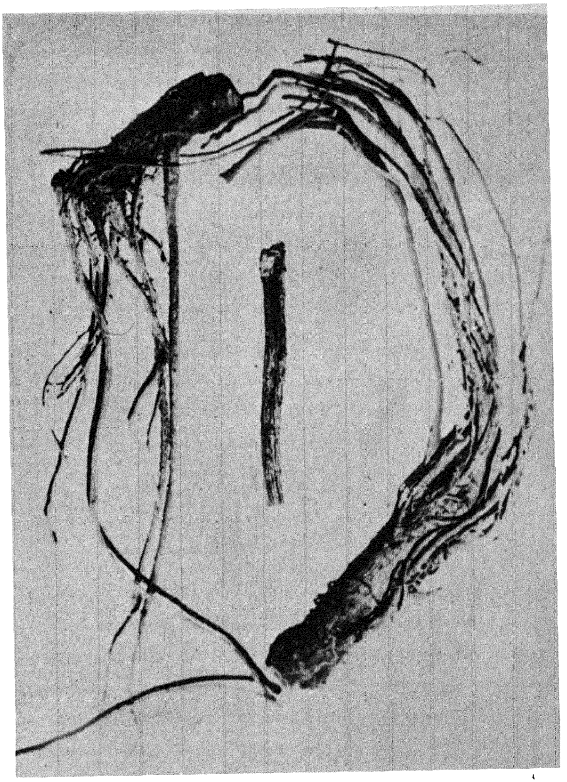


FIG. 118.—Derris roots (*Derris elliptica*). Derris has marked insecticidal properties, due to the presence of an active ingredient known as rotenone. (*Courtesy of H. W. Youngken and the American Journal of Pharmacy.*)

More recently it has been found that the dust made from ground roots has marked insecticidal properties, and at the same time is nonpoisonous to man, at least when taken through the mouth. The various species of *Derris* are climbing shrubs characteristic of the jungle undergrowth of tropical Asia from India and British

Malaya to the Dutch East Indies, Indo-China, and the Philippine Islands. The plants have a short trunk, 3 or 4 ft. in height and 4 in. in diameter, with numerous long branches that climb over the vegetation. Derris is cultivated in some regions. The two most important species are *Derris elliptica* and *D. trifoliata*. The active ingredients of derris roots include a resin and rotenone, a white crystalline substance. This may be extracted and used directly as an insecticide or as an ingredient of a soap.

Cubé

Cubé bark, obtained from *Lonchocarpus Nicou*, a leguminaceous vine locally common in South America, has recently come into prominence as an insecticide, owing to the fact that it contains even more rotenone than derris. The plant is cultivated in Brazil, Peru, and elsewhere. Three or four years of growth are required before the product is ready for the market. The South American Indians have been familiar with the toxic properties of cubé for a long time.

1935 Imports of Crude Drugs

	Pounds		Pounds
Aconite	11,533	Hoarhound	92,375
Agar	451,399	Hops	5,248,208
Aloes.	882,399	Ipecac	51,338
Belladonna	207,694	Jalap.	96,402
Betel	90,835	Licorice .	59,731,292
Buchu.	138,938	Marshmallow	31,611
Buckthorn.	98,342	Nux vomica.	2,888,450
Chamomile	139,440	Opium..	87,699
Coca...	245,221	Orris.	486,208
Colchicum	24,095	Papaw	116,422
Colocynth.	35,561	Psyllium	2,158,375
Cubebs	68,898	Pyrethrum	15,811,329
Derris	226,598	Quassia	625,151
Digitalis.	50,200	Quinine.	1,618,252
Ephedra	1,948,011	Rhubarb	135,062
Ergot..	252,400	Scammony	82,638
Gentian	351,806	Senna.	2,304,312
Ginseng. ...	12,187	Stramonium.	404,219
Henbane	89,485	Valerian	50,473

CHAPTER XII

FUMITORIES AND MASTICATORIES

In all ages and in all countries human beings have smoked or chewed various substances for pleasure, for some physiological effect, or in connection with their religious ceremonies. Some of these substances, such as spruce gum and chewing gum, are perfectly harmless, and are chewed merely because of their pleasant taste. The only benefit to be derived is possibly a psychological one brought about by the mechanical act involved.

The majority of the materials that are chewed or smoked, however, have a distinct stimulating or even narcotic effect, due to the presence of various alkaloids. Tobacco, betel, and cola are the least harmful of these drugs. At best they act only as mild stimulants and produce no effects on the consciousness of the user. Possibly the combustion products of tobacco, formed during smoking, are more harmful and may cause deleterious effects. It is a different matter, however, when we consider the great rivals of tobacco—coca, opium, and cannabis. These true narcotics contain alkaloids that are detrimental even in small amounts. When used in quantity, they may lead the addict to the lowest depths of depravity and degradation and cause stupor, coma, convulsions, and even death. The drug habit, brought on by the continued use of these narcotic plant products and their derivatives, is such a serious problem socially, as well as physiologically, that it is indeed fortunate that the sources of such drugs are relatively few in number.

TOBACCO

Tobacco is an important commodity the world over. It is used in one form or another by both civilized and uncivilized peoples. The tobacco plant is a native of tropical America. The original wild ancestor is not known for tobacco is very old and has been under cultivation for centuries. The use of tobacco originated with the Indians in connection with their religious rites. The plant had spread over North America before the coming of

the white man. Columbus was the first to note the use of tobacco by the Indians. The plant was introduced into Spain in 1558 and at first was grown only for its ornamental and medicinal value. Jean Nicot, for whom the plant was named *Nicotiana*, was chiefly responsible for bringing it to France. From there it

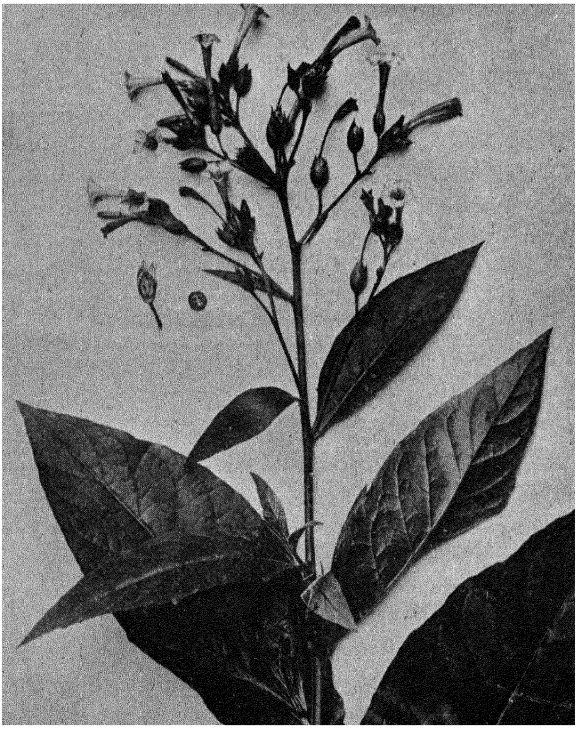


FIG. 119.—A tobacco plant (*Nicotiana Tabacum*) in flower.

rapidly spread over the rest of Europe, and to Africa, Asia, and Australia as well. The practice of smoking was not very general in Europe until 1586, but from that time on its popularity increased in spite of the opposition of the clergy and the governments, who almost taxed tobacco out of existence.

The narcotic and soothing properties of tobacco are due to the presence of the alkaloid nicotine. This active principle is extracted by the mucous membranes of the nose and throat.

The aroma and flavor are caused by essential oils and other aromatic substances developed during the curing process.

Kinds of Tobacco

Some 50 species of tobacco are known, but only two of these are of commercial importance. *Nicotiana Tabacum* is the source of most of the tobacco in use at the present time. This was the native tobacco of the West Indies and most of Central and South America. Although originally a tropical species, the plant has become adapted to cultivation in both subtropical and temperate regions. Over 100 horticultural varieties are known. Tobacco is a handsome unbranched annual, growing to a height of 3 to 6 ft., with large oval leaves that are usually sessile with clasping bases. The branching inflorescence (Fig. 119) bears pink flowers. The fruit is a capsule with numerous very small seeds. The leaves and stems are covered with glandular hairs, which secrete a resinous fluid and are very sticky to the touch.

Nicotiana rustica is a smaller hardier plant with yellow flowers. It probably originated in Mexico and still grows wild in parts of North America. This species was cultivated and smoked by all the eastern Indians before the coming of the white man. It was the first tobacco to be grown in Virginia, but was soon replaced by *N. Tabacum*. It is, however, still grown to some extent in parts of Central Europe, Northern Asia, and the East Indies. This tobacco is used for insecticidal purposes as well as for human consumption.

Cultivation of Tobacco

Tobacco is a costly and temperamental crop. The several types differ in their requirements as to warmth, moisture, and sunlight. The seeds are so small that it takes 400,000 to make an ounce. They are planted in seed beds, and the seedlings are transplanted when 4 to 6 in. high. The best soil is a light sandy loam, rich in humus, and well fertilized with potash and lime. Considerable cultivation of the fields (Fig. 120) both before and after transplanting is essential. After the plants get a good start, the terminal bud is removed in order to keep the strength in the leaves. Often inferior leaves and suckers are also taken off. When fully ripe, as indicated by a change in the color of the leaves, either the whole plants or the leaves alone are harvested.

Curing of Tobacco

The nicotine content develops as a result of the curing processes, which vary considerably. The leaves may be dried in sheds over fires of charcoal or they may be flue cured. In this method hot air is carried by flues to the curing sheds, and the tobacco is not exposed directly to the fire. Air curing is extensively practiced in specially ventilated barns (Fig. 121), in which the humidity can be carefully controlled. The curing process is really a dry

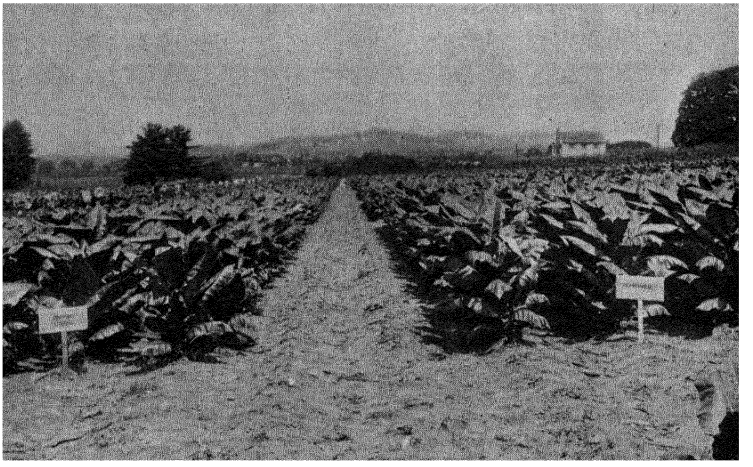


FIG. 120.—Tobacco growing in the Connecticut valley, Massachusetts. (*Courtesy of the Agronomy Department, Massachusetts State College.*)

fermentation. It takes from three to six weeks, during which time the green leaves turn a yellow-brown and become tougher. Eventually the leaves are piled up in small heaps and allowed to undergo a true fermentation for another four to six weeks. This second fermentation causes the development of the aroma and bouquet. Finally the leaves are sorted into grades and aged.

Grading of Tobacco

The proper grading of tobacco is a very specialized task and can be done only by experts. A single crop may yield as many as 70 different grades. Tobacco growers recognize *classes*, based on

the future use of the product, such as pipe tobacco, cigar wrappers, cigar fillers, chewing tobacco, and cigarette tobacco; *types*, based on color, flavor, strength, and the method of curing; and *grades*, based on size, aroma, texture, and similar characteristics.

It is difficult to define a good tobacco for the several classes differ as to their requirements. Cigar wrappers require leaves that are free from flavor and are thin and elastic, with small veins and uniform color. Tobacco for wrappers is often grown under shade. This provides a more uniform environment and product,



FIG. 121.—Interior of a tobacco shed on a farm near Mitchell, Ind. (*Reproduced by permission from MacDonald, Then and Now in Dixie, Ginn and Company.*)

together with greater protection from injury. Cigar fillers must have a sweet, pleasant flavor, and must burn evenly with a firm white ash. Cigar tobacco is usually air cured. Chewing tobacco requires leaves that are rich in flavor, tough, gummy, and highly absorptive to the various flavoring materials that are added. It is usually air cured. It is often necessary to use blends, for all the requisites may not be present in a single type of leaf. Light-colored leaves which lack gummy substances are used for cigarettes and pipe tobacco. They are air cured or flue cured. As in the case of chewing tobacco, blends are extensively used. The darkest tobacco, cured over fires, is used chiefly for the export trade and to some extent for pipe tobacco. Poorer grades and waste are used for snuff.

Production of Tobacco

The United States has always led the world in the production of tobacco. This crop was first grown in 1612, and was first exported in 1618 from Jamestown. From the very outset tobacco was the backbone of the Virginia colony, even serving as currency. There grew up around its cultivation in tidewater Virginia a culture which has never been equalled in America and which flourished for two centuries. After the Revolution the industry declined, owing partly to the competition of other countries and partly to the exhaustion of the soil. Gradually the industry moved westward into the Piedmont region of Virginia and North Carolina, and the great estates gave way to small farms. Tobacco has been grown in New England to some extent from the beginning, but the crop has been important only since 1795. Today the tobacco industry is specialized since certain areas are better suited to one kind of tobacco than to others. Altogether tobacco is grown on some 375,000 farms located in 28 different states. North Carolina and Kentucky, however, produce 60 per cent of the total amount. Flue-cured and Burley are the chief types grown, comprising about 80 per cent of the entire production. Fire-cured, cigar filler, cigar binder, dark air-cured, Maryland, and cigar wrapper follow in the order named.

Flue-cured tobacco is grown in Virginia, North Carolina, South Carolina, Georgia, and Florida. Sixty per cent of the crop is exported and the balance is used for cigarettes and pipe and chewing tobacco. Two types of *light air-cured* tobacco are grown: the Burley, used for cigarettes and pipe and chewing tobacco, and grown in Kentucky, Indiana, Ohio, West Virginia, Tennessee, North Carolina, and Virginia; and the Maryland, produced in southern Maryland and used for cigarettes and export. *Fire-cured* tobacco, used chiefly for the export trade and for snuff and plug wrappers, is produced in western Kentucky, northwestern Tennessee, and central Virginia. *Dark air-cured* tobacco is a product of the eastern part of Kentucky and Tennessee and north central Virginia. It is used for export and for chewing and plug tobacco. Tobacco for *cigar wrappers* is grown chiefly in the Connecticut valley, usually under shade, and to some extent in Georgia and Florida. The Connecticut valley also produces *cigar-binder* tobacco, as do Wisconsin, New York, and Pennsyl-

vania. *Cigar-filler tobacco* comes from Lancaster County, Pennsylvania and also from Ohio, Georgia, and Florida.

In 1930, the banner year, 2,110,000 acres were devoted to tobacco and the crop amounted to 1,647,377,000 lb. More recently tobacco growing has been considerably curtailed, but the 1935 figures show that 1,437,100 acres were harvested and 1,296,810,000 lb. were produced. In spite of the large production, a considerable quantity of tobacco is imported each year. The utilization of the tobacco crop is interesting. In 1934, 374,658,000 lb. were exported, 375,383,000 lb. were used for cigarettes, 289,024,000 lb. for smoking and chewing tobacco and snuff, and 111,123,000 lb. for cigars.

The most spectacular phase of the tobacco industry has been the amazing development of the cigarette in recent years. As late as the 1880's only a few were made, chiefly Richmond Straight Cuts and Sweet Caporals. These were consumed almost entirely in the East, for manufactured cigarettes made slow progress in the West. In 1894 the Egyptian cigarette appeared and slowly made headway even though it was expensive. Soon the American manufacturers began to add Turkish tobacco to improve the burning qualities of their product. Then came the World War and instantly cigarettes came into great demand and their use soon became nation wide. In 1913, 3,000,000,000 cigarettes were produced. This number had increased to 15,000,000,000 in 1914, 46,000,000,000 in 1915, 52,000,000,000 in 1921, 109,000,000,000 in 1928, and 130,000,000,000 in 1934.

Other large tobacco-producing countries are India, Russia, the Dutch East Indies, the Philippine Islands, Japan, Greece, Turkey, and Brazil. Many other areas produce high-grade tobacco in smaller amounts. This is particularly true of Jamaica and other West Indian islands and Asia Minor.

The various nations differ greatly in the grade of tobacco used and the type. England, a great pipe-smoking country, demands the best and strongest grades. Germany prefers a thick leaf, rich in oil, and reddish in color. Switzerland demands the best quality, Italy and Austria a good grade, while France and Spain are satisfied with the poorer grades. The southern European countries prefer cigars and cigarettes, while the northern ones use pipes. Similar differences hold true in the other nations of the world. In many countries tobacco is a government monopoly.

BETEL

Probably more people chew betel nuts than any other masticatory. The number has been estimated at 200,000,000. The desire for betel is very great and it is chewed by all classes of people at all times. Over 50,000 tons of the nuts are used annu-

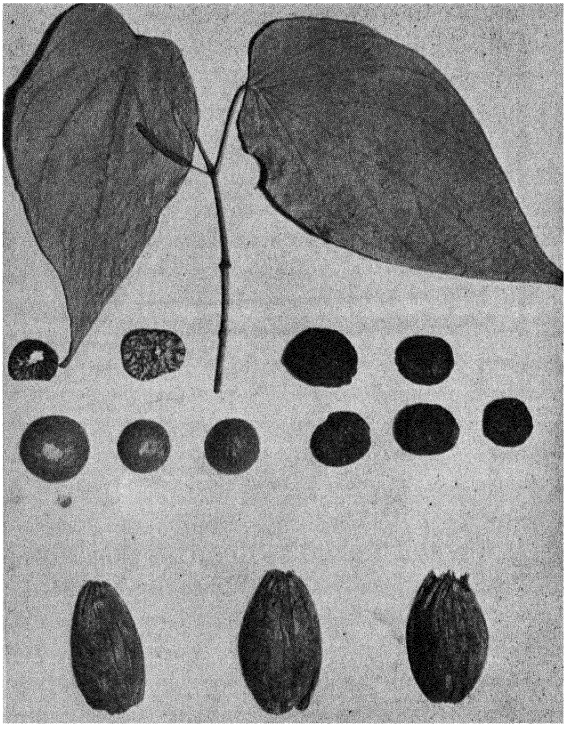


FIG. 122.—Materials used in betel-nut chewing. Above, leaves of the betel pepper (*Piper Betle*); center, betel nuts (*Areca Catechu*) with husk removed and some of the nuts cut; below, betel nuts with the husk surrounding the fruit. (*Courtesy of the Botanical Museum of Harvard University.*)

ally. The habit is indulged in from Reunion and Zanzibar to India, Ceylon, and southeastern China, and in the East Indies, Philippine Islands, and some of Oceania.

Betel nuts or areca nuts are the seeds of the betel-nut palm (*Areca Catechu*). This palm is a native of Ceylon and Malaya, but is cultivated wherever the nuts are used. The method fol-

lowed by betel users is quite complex. Fresh leaves of the betel pepper (*Piper Betle*) are smeared with lime and cutch. Slices of the nut in any stage of maturity are placed on the leaf, and sometimes cloves, tamarinds, or other flavoring materials are added. The whole mass is placed in the mouth and allowed to remain there. A copious flow of saliva is stimulated. The betel habit is particularly disgusting from a white man's point of view for the saliva and teeth are turned a brown or red color, depending on the amount of lime used. Eventually the teeth become blackened. The essential ingredients (Fig. 122) are usually kept in small boxes that can be easily carried on the person, but they are readily obtainable everywhere.

Although the seeds contain a narcotic principle, which may be used in medicine, the betel habit is not harmful. As in the case of tobacco, betel does not alter consciousness in any way, but merely produces a mild stimulation and feeling of well-being. The alkaline juice may even be helpful by preventing overacidity. The betel habit is so widespread today that it indicates a long history in the past. It was first described by Herodotus in 340 B.C.

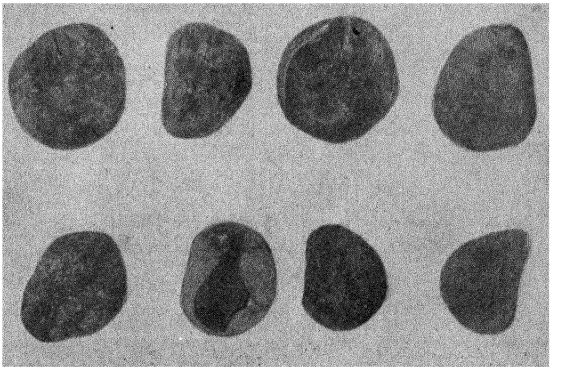


FIG. 123.—Cola nuts, the seeds of *Cola nitida*.

COLA

The seeds of the cola tree (*Cola nitida*), known as cola or kola nuts, are extensively used in many parts of tropical Africa as a masticatory. This tree, a tall species with a straight trunk reaching a height of 50 to 65 ft., grows wild in the forests of tropi-

cal West Africa. It is also cultivated in this region and the adjacent Sudan, and has been introduced into Jamaica, Brazil, India, and other parts of tropical Asia. The fruit consists of star-shaped follicles which contain eight hard, plano-convex, fleshy seeds with a reddish color and the odor of roses. These "nuts" (Fig. 123) are marketed fresh and are usually chewed directly, although powdered nuts may be used.

Cola has long played an important part in the social, religious, and commercial life of the African natives. It was first reported in the twelfth century. The nuts are in great demand and the natives will go to considerable trouble to obtain them. Although bitter at first, they leave a sweet taste in the mouth. The use of this masticatory results in a slight stimulation and temporary increase in physical capacity. It is said to lessen hunger and fatigue. Cola is the most complex of the caffeine-containing products. It not only contains 2 per cent caffeine, but an essential oil and a glucoside, kolanin, as well. The stimulating effect of cola is due in part to the caffeine and in part to the kolanin, which acts as a heart stimulant. Old nuts tend to lose their kolanin, and so are less invigorating. The chewing of cola nuts has no effect on the consciousness and produces no other deleterious results.

THE TRUE NARCOTICS

We have already seen that the narcotic plants contain alkaloids that are valuable in medicine, when used in exceedingly small amounts. They are used to relieve pain, produce sleep, and quiet anxiety and fears. It is so easy to produce serious physiological effects, however, that they must be used with the utmost discretion and only under a physician's direction. There is no possible excuse for their use under any other conditions.

The narcotic drugs vary considerably in their effects on the human system. Cocaine and opium act as sedatives on mental activity and bring about a state of physical and mental comfort. This is accompanied by a diminution, and even suspension, of emotion and perception, together with a lowering and often complete suppression of consciousness.

Cannabis, peyote, fly agaric, and the solanaceous narcotics, on the other hand, cause cerebral excitation and bring about hallu-

cinations, visions, and illusions. Their use causes intoxication and may be accompanied or followed by unconsciousness or other symptoms that indicate that the brain is no longer functioning normally.

Kavakava is a sleep-producing drug and tends to induce a hypnotic state.

Coca

The chewing of the leaves of the coca plant (*Erythroxylon Coca*), already mentioned as the source of the drug cocaine, is a

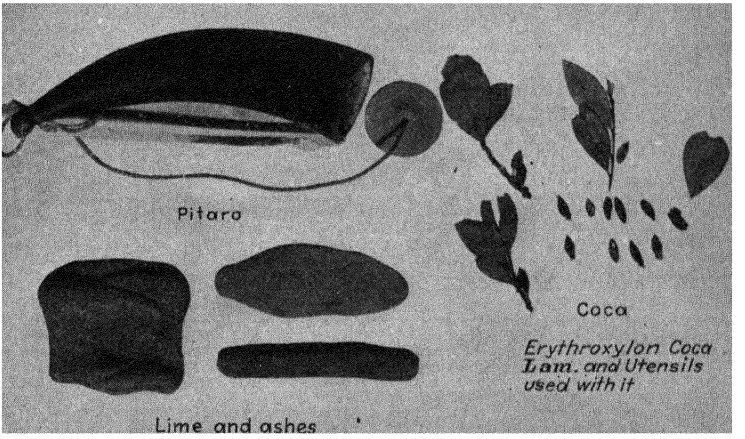


FIG 124.—Materials used in coca chewing. Upper left, the pitaro, a container for lime; lower left, lime and ashes; right, leaves and fruit of the coca shrub (*Erythroxylon Coca*). (*Courtesy of the Botanical Museum of Harvard University.*)

centuries-old custom among the Indians of Peru and adjacent parts of South America. The discovery of the plant and its properties is shrouded in mystery. It was highly esteemed by the Incas, who used it as an emblem of royalty. The use of coca gradually spread from the higher classes among the common people, and Pizarro found it in general use in 1553.

The Indians who use coca can resist physical and mental fatigue and work for long periods without food or drink. The average consumption is 25 to 50 grams daily. The chewing of coca is followed, after a short period of rest, by greatly stimulated activity. The mind is affected to such an extent that the consumer is

enabled to forget his hunger or other miseries. The custom soon becomes a habit and leads to physical deterioration, sickness, and even death. The habit is especially bad for white men. The leaves are chewed alone, or mixed with lime and the ashes of some plant, such as quinoa. Coca chewing (Fig. 124) is so indispensable and widespread in South America that very little coca is exported, although the plant is widely cultivated on the eastern slopes of the Andes from Peru to Argentina. It is also cultivated to some extent in Java and India. The use of coca, and its derivative cocaine, is subject to the strictest regulations in most countries.

Opium

Opium is a very old narcotic. As we have seen, it is the dried juice that exudes from injured capsules of the opium poppy. Originating probably in Asia Minor, the use of opium soon spread westward. The drug was known to the Greeks and Egyptians and perhaps to the earlier Lake Dwellers of Switzerland. In its eastward dispersal it had reached Persia, India, and China by the eighth century, and since then has spread all over the world. When properly utilized, opium and the alkaloids derived from it are valuable medicinally and have proved a great blessing to mankind in the relief of pain. Excessive use of the drug, however, and the resulting opium habit have been and still are the cause of unbelievable suffering and evil. In spite of every effort to stamp out the habit, it seems to be increasing. This is particularly true of the Orient, where opium has taken a toll of millions of lives

It is an all too easy step from the use of a small quantity of opium as a soporific, or for the pleasure of the moment, to the point where it becomes necessary for the very existence of the unfortunate addict. The immediate effects of taking opium are pleasurable, and alluring dreams and visions are induced. Continued use, however, leads to delirium and death. The opium addict soon loses the will power necessary to resist the craving. Even if he develops sufficient moral resistance, the withdrawal pains are so severe that it becomes virtually impossible for him to continue his abstinence.

In India opium is usually eaten and the habit is common to all classes of society. So great is the demand that the cultivation of

the opium poppy is one of the most profitable industries in the country. In earlier days opium was openly exploited by the Portuguese, the Dutch, and the English in turn. Today attempts are being made by the various governments to regulate the production and trade in opium. Unfortunately, because of the large revenues that can be derived, such attempts are likely to be only half-hearted and consequently only partially successful. In India immense quantities of opium are available in the open



FIG. 125.—A field of opium poppies (*Papaver somniferum*) in southern Manchuria. (*Photo by F. N. Meyer, courtesy of the Arnold Arboretum*)

market, although the British government has a monopoly on the drug and attempts to restrict its sale to accredited buyers only.

Conditions in China are much worse. Here the usual method of consumption is opium smoking—placing a small pellet in the bowl of a special pipe and inhaling the fumes. In this way more morphine is said to be absorbed and the effects on the system may be greater. Until recently few attempts have been made to stamp out the practice. In the past the nation as a whole has shown in its mental and physical characteristics the effects of the opium habit. What the future holds for China is problematical for it is claimed that more opium is grown and used today than ever before. It has been estimated that the consumption is eight times that of the rest of the world together. Every

province grows the poppy (Fig. 125) and the crop may be so profitable that little food is raised, with the result that famine is always hovering over the land.

In Europe and the United States, although opium, morphine, codeine, and the other derivatives are used to a much less extent than in the Orient, the smuggling and use of these narcotics are matters of grave concern. Laws relating to narcotics cannot be too rigidily enforced. In countries where the habit has a strong foothold, opium is not only a social problem but often the cause of international complications as well. China and India have had serious differences over the opium trade. The suppression of the production and use of opium and similar narcotics is one of the greatest problems facing the world today. The League of Nations has rightly devoted considerable attention toward setting up prohibitive regulations and other methods of dealing with the situation.

Cannabis

The hemp plant (*Cannabis sativa*), already discussed as the source of a textile fiber and a drying oil, also yields a narcotic drug. The dried flowering tops of the female plants, pressed together into solid masses, constitute the official "cannabis indica." This drug is used in medicine to relieve pain and in the treatment of hysteria and various nervous disorders. The active principle is resinous in nature and contains three or four very powerful alkaloids. Hemp is often cultivated solely as a drug plant.

The use of hemp as a narcotic stimulant is very old, extending back at least 2000 years. The plant was used by the Assyrians and was familiar to Herodotus. At the present time the habit is indulged in chiefly in India, Mongolia, and other parts of Southern Asia, Asia Minor, and Northern and tropical Africa. "Hashish," as the plant is called, is consumed in several different ways. The dried, infertile female flowering tops are smoked. These are known as "ganza." A beverage, known as "bhang," is made from coarsely powdered foliage leaves and water. The naturally exuded resin, or "charras," is also smoked. This is the most powerful form of the drug. The resin is obtained by rolling and treading on the leaves or by having natives run violently through a mass of the plants. The resin from broken leaves clings to the

clothes of the runner and can be removed easily. Seeds and leaves are sometimes smoked.

Cannabis in its various forms often produces serious results for the consumer. It causes a stupefying and hypnotic effect, accompanied by hallucinations, agreeable and often erotic dreams, and a general state of ecstasy. The addicts, while under the influence of the drug, are apt to be happy and noisy and may even become fanatical and commit murder. Cannabis has been of little importance in the United States, but recently the use of marijuana cigarettes, illicitily made from hemp, seems to be increasing, in spite of all efforts to stamp out the habit.

Peyote

A cactus, *Lophophora Williamsii*, is the source of peyote or mescal buttons. This species is indigenous to Mexico and the southwestern United States, occurring on dry, arid plateaus in a

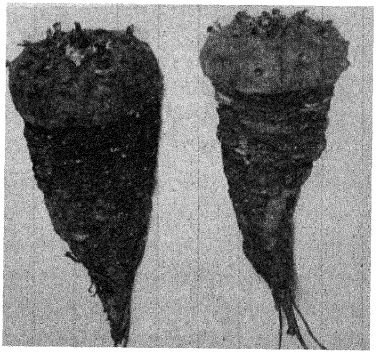


FIG. 126.—Peyote (*Lophophora Williamsii*). The tops of these diminutive cacti are known as mescal buttons. Peyote has powerful narcotic properties. A sacred cult devoted to its use exists among the Indians of the southwestern United States and adjacent Mexico. (*Photo by R. E. Schultes.*)

limited area bordering on the Rio Grande. The cactus resembles a huge carrot (Fig. 126) with all parts of the plant, except a buttonlike top, below ground. These tops are round and flattened and have a wrinkled surface. They do not bear spines, but only little tufts of silky hairs. Some of the buttons are very tiny, while others may measure as much as 2 or 3 ft. in diameter.

Mescal buttons contain several very powerful alkaloids with narcotic properties. The native Indians of the region have used peyote for hundreds of years in connection with baptisms and other religious ceremonies. In spite of efforts to stamp out the habit, it still flourishes, owing primarily to the existence of a sacred cult devoted to its use. The buttons in either a fresh or dried state are chewed until they are soft. They are then rolled up in the hand into little pellets which are swallowed. Sometimes a beverage is prepared by boiling the buttons. Peyote produces a state of ease and well-being, accompanied by visions and hypnotic trances. The addict finds himself in a world full of new sensations and pleasures. Peyote is also used extensively by the Indians for its supposed medicinal value. It is considered by them to be a panacea for most bodily ills.

Fly Agaric

The fly agaric (*Amanita muscaria*) is known in Europe, Asia, and America as one of the most poisonous of fungi. In spite of this fact, quantities of this mushroom are consumed in Siberia and other parts of Northeastern Asia for its intoxicating effect. Dried agarics are chewed until soft, rolled into sausage-shaped pieces, and swallowed. At other times they are used in milk, water, or the juice of berries as a beverage. The use of this fungus produces hallucinations and illusions, accompanied by giddiness, involuntary words and actions, and finally unconsciousness. Two small fungi are sufficient to produce an intoxication that will last for a whole day. The habitual use of the narcotic will completely shatter the nervous system, yet the craving for the drug among its addicts is too great to be denied.

Caapi

The Indians of the northwestern part of the Amazon basin use the caapi (*Banisteriopsis Caapi*) as the source of a narcotic beverage. This plant is a liana, growing naturally in the virgin forests of Ecuador, but cultivated elsewhere. The lower part of the stem of the liana is cut off, cleaned, and boiled. Caapi is used in the religious ceremonies of the natives. It produces visions, dreams, and other mental disorders.

Solanaceous Narcotics

Several members of the *Solanaceae* contain alkaloids that produce disorders of the brain and marked excitation when smoked or eaten. These narcotics are often responsible for some of the incomprehensible acts of fanatics in the East and elsewhere.

The genus *Datura* is extensively used in all the continents except Australia for its narcotic properties, and several different species are concerned. The Jimson weed (*D. Stramonium*), the source of the drug stramonium, was known as a narcotic as early as 37 A.D. It still is one of the favorite sources of "knockout drops" in the tropics. The maikoa (*D. arborea*), a subtropical shrub of South America, is much used by various tribes of the Amazon region for its narcotic properties. Other species are similarly used elsewhere, all of them producing comparable effects, such as sense illusions and motor disturbances, together with senseless activities and loss of memory.

Other important solanaceous narcotics include the henbanes and pituri. The black henbane (*Hyoscyamus niger*) has long been used as a poison and a sorcerer's potion, and to bring about visions and prophecies. *H. muticus* is smoked in Northern Africa and India for its intoxicating effect. Large quantities of the pituri (*Duboisia Hopwoodii*) are chewed and smoked by the natives of Australia for its stimulating and narcotic effects.

KAVAKAVA

The use of kavakava, which is almost universal throughout Oceania, produces different results from those hitherto discussed. The beverage acts as a sedative, a soporific, and a hypnotic, bringing about pleasant dreams and sensations. Excessive use is apt to produce skin diseases and weaken the eyesight. The active principle is a resinous substance that is stimulating in small amounts. The source of kava, as it is sometimes called, is a bushy shrub 6 to 8 ft. tall, with rounded or cordate leaves. This species, *Piper methysticum*, is indigenous to Fiji and other Pacific islands, but is now grown everywhere in the South Seas. The thick, knotty, grayish-green roots are the important part. These are dug up and the bark is removed. After the roots are thoroughly cleaned, they are cut up into small pieces. These pieces are chewed until they are fine and fibrous and are then placed in a

bowl with water and allowed to ferment. Formerly while the roots were being chewed the saliva was ejected into bowls and this constituted the beverage. After straining, kava is a grayish-brown liquid and is very refreshing. It is closely connected with the entire social, political, and religious life of the people. It is used in connection with festivals and religious observations, as a soporific, as a token of good will, and as a daily beverage.

CHAPTER XIII

THE HISTORY AND NATURE OF FOOD PLANTS

THE HISTORY OF FOOD PLANTS

The most remarkable fact concerning the food plants in use in the world today, and for that matter the industrial plants as well, is their great antiquity. Most of them were domesticated from wild ancestors long before the beginning of the historical period, and all available records indicate that they were as familiar to the peoples of the ancient world as they are to us. Comparatively few new plants have been developed during the last 2000 years, although the older ones have been greatly altered and improved in response to the increasing complexity of man's existence.

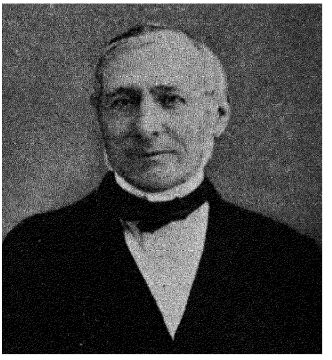


FIG. 127.—Alphonse De Candolle (1806–1893), from a photograph taken in 1866. (*Courtesy of the Gray Herbarium*)

The history of our useful plants and their influence on civilization has always been of interest to botanists and ethnologists. Many investigations have been carried on in an attempt to determine their age and place of origin, as well as their cultural history.

The Work of De Candolle.—The classic work dealing with this phase of botany is De Candolle's "L'origine des plantes cultiveés," which appeared in 1883. So careful and painstaking was his work that few of his conclusions have had to be altered in the light of more recent studies. De Candolle (Fig. 127) based his conclusions on a great variety of evidence: the works of Theophrastus, Dioscorides, and other old historians; Chinese writings; archeological and ethnological data, such as the monuments of Egypt, the ruins of Pompeii, the remains of the Lake Dwellers of

Europe, and the Inca ruins of South America; philological indications, involving the names of plants in Hebrew, Sanskrit, and other ancient languages; and botanical conclusions based on distribution, number of varieties, presence or absence of wild types, length of cultivation, and similar matters. He arranged the useful plants in six classes, and it will be interesting to give a few examples of each of these groups:

A. Old World Species Cultivated for Over 4000 Years

almond	date	millet	rice
apple	eggplant	mulberry	sorghum
apricot	fig	olive	soybean
banana	flax	onion	tea
barley	grape	peach	turnip
broad bean	hemp	pear	watermelon
cabbage	mango	quince	wheat
cucumber			

B. Old World Species Cultivated for Over 2000 Years, and Perhaps Longer

alfalfa	chestnut	mustard	poppy
asparagus	cotton	nutmeg	radish
beet	garden pea	oats	rye
breadfruit	grapefruit	orange	sugar cane
carrot	lemon	pepper	walnut
celery	lettuce	plum	yam
cherry	lime		

C. Old World Species Cultivated Probably for Less than 2000 Years

artichoke	endive	okra	raspberry
buckwheat	gooseberry	parsley	rhubarb
coffee	horseradish	parsnip	strawberry
currant	muskmelon		

D. New World Species of Ancient Cultivation, More than 2000 Years

cacao	maize	sweet potato	tobacco
kidney bean	maté		

E. New World Species Cultivated before Time of Columbus Antiquity not Known

avocado	peanut	pumpkin	squash
cotton	pineapple	quinoa	tomato
guava	potato	red pepper	vanilla
Jerusalem artichoke			

F. NEW WORLD SPECIES CULTIVATED SINCE THE TIME OF COLUMBUS

allspice	cinchona	gooseberry	plum
blackberry	cranberry	pecan	rubber
black walnut	dewberry	persimmon	strawberry
blueberry			

From these examples it can readily be seen that our most valuable economic plants, including the cereals, most of the vegetables and fruits, tea, coffee, cocoa, and the fiber plants, were discovered, utilized, and cultivated by man thousands and thousands of years ago.

It is even more difficult to determine the native homes of our cultivated plants. Obviously they must have been derived at some time in the remote past from wild ancestors, which originally had a restricted distribution. In most cases these wild forms no longer exist, or they have been carried by man far from their original home. For these and many other reasons it is a well-nigh impossible task to come to a definite conclusion as to the place of their origin.

The Work of Vavilov.—An important work which throws some light on this point of cultivated-plant origins is that of Vavilov, which appeared in 1926. His conclusions are based on a variety of facts obtained from sources different from those of his predecessors. He considers such features as the anatomy, genetics, cytology, distribution, and diseases of the plants concerned.

A valuable conclusion in Vavilov's work is that many of our cultivated species of first rank, the primary crops as he calls them, had a diversified rather than a single origin. In the case of wheat, for example, the author points out that there were at least two distinct centers of distribution. The soft wheats came from Southwestern Asia, while the hard wheats originated in the Mediterranean region. Similarly barley was derived from Southwestern Asia, North Africa, and Southeastern Asia.

Another point is concerned with the so-called secondary crop plants. It is the contention of the author that these were originally weed companions of the primary crops. These weeds could not be eliminated and were either ignored or tolerated by the farmer. In regions that were favorable for the primary crops the weeds were of little importance. In unfavorable areas, however, the weeds tended to become more and more prominent, gradually replacing the primary crop, and eventually becoming

established as a cultivated crop. Rye and oats are conspicuous examples of such plants.

A final contention is that the great centers of distribution of our cultivated crops were always in mountainous regions, and that the greatest amount of diversity occurred in such areas. Vavilov in general recognizes the four centers of distribution to be discussed below, with the addition of a fifth area in Abyssinia and adjacent parts of Northern Africa. He also suggests the possibility of a sixth center in the Philippine Islands where rice and coix may have originated.

ORIGIN AND DISTRIBUTION OF FOOD PLANTS

At the present time the available data seem to establish the fact that there were at least four chief centers in which our economic plants originated, and from which they were later dispersed all over the world: (1) Southwestern or Central Asia, the mountainous region from India to Asia Minor and Transcaucasia; (2) the Mediterranean region; (3) Southeastern Asia; and (4) the highlands of tropical America.

The parallelism between the history of mankind and the history of his domesticated plants (and animals as well) is obvious. It was in this same Central Asian plateau that scientists tell us man had his origin, from which the human race was dispersed. Thus from the earliest beginnings man had at his disposal various food plants, and he must have been dependent on them to a great extent for his existence. For countless ages he was a nomad, wandering from place to place, content merely to gather the edible fruits, grains, seeds, and tubers as he needed them, possibly for temporary storage in small amounts. At some later period in his history he began to make primitive attempts at cultivating these useful plants by sowing seeds in some favorable location. Whether these first attempts at agriculture were accidental or purposeful, they were of profound importance for they changed the whole nature of his existence. Of necessity he had to forsake his nomadic life and remain in one place at least long enough to harvest his crop. In so doing he took the first step toward becoming civilized, for agriculture is the only mode of existence that has enabled men to live together in communities and accumulate the necessities of life. The establishment of agriculture was

of the utmost importance to man and probably represents the most significant single advance in his development.

Gradually these first simple types of plant culture were replaced by an agriculture of a much higher grade, which eventually led to the building up of the great nations of antiquity. These ancient civilizations were restricted in area, for they developed only in those regions where the useful plants that were the foundation stones of their existence were native. And so we find that Asia Minor and adjacent areas in Southwestern Asia, the Mediterranean region, Southeastern Asia, and the tropical American highlands were the locations of the older civilizations. The presence of valuable plants in all these regions was the most important factor in the successful development of agriculture, although in all these areas climate and soil conditions were very favorable. The climate was equable, with no extremes of heat and cold; the soil was fertile; and there was either ample rainfall or irrigation could be practiced.

In *Central Asia* the native plants included alfalfa, apple, barley, broad bean, buckwheat, cherry, flax, garden peas, garlic, hemp, lentil, mulberry, olive, onion, pomegranate, plum, quince, radish, rye, and spinach.

The *Mediterranean region* was the home of the artichoke, asparagus, cabbage, cauliflower, cotton, fig, horseradish, millet, parsnip, parsley, and rhubarb. Common to both these areas were the almond, carrot, carob, celery, chestnut, grape, lettuce, mustard, turnip, and walnut. Wheat is also a native of some part of this combined area. Whether it was indigenous to Syria and Palestine, to Turkestan or Mesopotamia, or perhaps had a multiple origin, it was early available for all the nations of the region.

In *Southeastern Asia* the banana, breadfruit, millet, peach, persimmon, orange, rice, soybean, sugar cane, and yam were native; in the *American area* cacao, American cotton, kidney and lima beans, maize, potato, squash, tobacco, and tomato were indigenous.

It is interesting to note that a cereal was available in all these cultural areas. Ancient agriculture was based chiefly on these cereals, just as modern agriculture is. Their highly nutritious seeds were the staff of life 5000 and 10,000 years ago, and have remained so up to the present time. It was the cultivation of wheat in the fertile valleys of the Tigris and Euphrates rivers that

made possible the great nations of Biblical time, Chaldea, Assyria, and Babylonia. Egypt, Greece, and Rome had both wheat and barley available. Rice was the basis of the restricted civilization that developed in the valleys of the Hwang Ho and Yangtze Kiang rivers and led to the development of the great Chinese empire. The primitive peoples of the highlands of tropical America cultivated the native maize, the foundation of the remarkable civilizations that persisted until overthrown by the Spanish invaders. In all these cultural areas the history of agriculture has been the same: first, the gathering of the edible portions of wild plants; then the primitive cultivation of certain species best adapted to man's needs; and finally the evolution of a high-grade agriculture, which involved the breeding of new varieties, improvements in cultivation, irrigation, and similar features. Because of this similarity in the development of agriculture, particularly between the Old and the New World, many authorities have believed that the American civilizations must have had some contact with those of the Old World and been influenced by them. The evidence, however, seems to show that agriculture in this continent has had an entirely separate development and that the resemblances which occur are only chance ones.

THE NATURE OF FOOD PLANTS

Food is necessary for the existence of all living things. The various substances that constitute the food of plants and animals are used by them either in the formation of the living protoplasm, the building up of their bodily structure, or as a source of energy. We have already pointed out, in Chap. I, that green plants alone are actually able to manufacture food from raw materials. Man and the other animals must take their food ready-made, and so are dependent, either directly or indirectly, on plants. Fortunately for the animal world, plants manufacture much more food than they can utilize immediately, and they store up this surplus as a reserve supply for future use. It is this supply of reserve food that man appropriates for his own use. The essential foods, carbohydrates, fats, and proteins, each valuable in its own way in man's metabolism, are all available in plants. So, too, are mineral salts, organic acids, vitamins, and enzymes, which are also necessary for his well-being. Thus it is

possible for man, if he so desires, to live entirely on a vegetarian diet.

Plants utilize roots, stems, leaves, fruits, and seeds, to a greater or less extent, for the storage of reserve food. The most important of these from the standpoint of man are the dry fruits and seeds. In this category are found the cereals and small grains, the legumes, and the nuts. All these contain a very large amount of nutritive material and have a proportionately low water content. This latter fact enhances their value to man, for they can be stored and transported easily. Roots, tubers, bulbs, and other earth vegetables are next in importance as sources of food for human beings, and the lower animals as well. Their value is lessened by their high water content. The leafy parts of plants, the greens, salad plants, and other herbage vegetables, contain comparatively little stored food. However, they are necessary because of the vitamins and mineral salts they contain and the mechanical effect of the indigestible cellulose material. The same is true of the fleshy fruits, which may also contain various organic acids. In the present discussion the food plants will be considered under the following headings: cereals, small grains, legumes, nuts, earth vegetables, herbage vegetables, fruit vegetables, and fleshy fruits.

It will obviously be impossible to discuss, or even list, all the plants used for food throughout the world. Hundreds of species, both wild and cultivated, are used only by primitive races or in restricted areas. An attempt will be made to consider the outstanding food plants of the United States and Europe, together with a few of the more conspicuous ones of other countries.

Before proceeding to this discussion, which will be concerned primarily with the higher plants, some reference will be made to the lower plants as sources of food.

THE LOWER PLANTS AS SOURCES OF FOOD

Fungi

The use of mushrooms, truffles, and other fungi as sources of food is very ancient, possibly as old as man himself. The first records go back as far as the fifth century B.C. Mushrooms were well known to the Greeks and were highly prized by the Romans. During the Middle Ages the consumption of these edible fungi

was enormous. Today they are eaten by both primitive and civilized peoples. Not only are wild forms utilized, but the cultivation of mushrooms is extensively carried on in Europe, the United States, and many parts of the Orient.

Mushrooms

Mushrooms occur naturally in fields, pastures, and woods. They represent the reproductive stage of certain of the higher fungi. The vegetative stage of these fungi consists of masses of fine threads, or hyphae, which constitute the mycelium. This mycelium extends in all directions through the soil, deriving its nourishment saprophytically from decaying organic matter. Sooner or later, depending in part on favorable environmental conditions, the visible spore-bearing stage is produced. It may take years for this to develop.

Space will not permit a discussion of the many edible wild mushrooms. These are more delicate in flavor and more palatable than the cultivated forms. However, great caution is necessary in distinguishing them from the poisonous species, familiarly known as toadstools, for the resemblance is often very close. No hard and fast rules can be laid down which absolutely separate the two groups. Definite and accurate knowledge as to the identity of any particular species is necessary. It is wisest to discard any mushroom that resembles a poisonous form, even though it is known to be edible.

Cultivation of Mushrooms.—The cultivation of mushrooms dates back to the beginning of the seventeenth century. Today it is carried on with a high degree of efficiency, particularly in France, England, and the eastern United States. The most important species utilized is the common meadow mushroom (*Agaricus campestris*). Propagation is by means of spores, or more usually by using spawn. Spawn consists of masses of mycelium compressed into little bricks. Suitable environmental conditions are essential for development. There should be little or no light, plenty of moisture, and a constant temperature, with 55 to 58°F. the optimum. The soil should be rich in organic matter, stable manure serving as an excellent medium. Cellars, tunnels, and caves afford ideal situations for growing mushrooms. The important French industry makes use of abandoned quarries and mines.

Under these conditions spores germinate, or the mycelium resumes its growth, ramifying through the soil and in about six weeks forming little buttons on the surface of the soil. Eventually the buttons enlarge to form a chamber in which the gills develop. This chamber is raised up on a short fleshy stalk and, when mature, opens out into the characteristic umbrellalike pileus with the gills on the underside. The innumerable spores are produced on the gills. Mushrooms (Fig. 128) are gathered in the button stage, or before they are fully mature. The mycelium continues to bear from six to eight months.



FIG. 128.—Mushrooms (*Agaricus campestris*) grown under cultivation. (*Courtesy of the Massachusetts State College.*)

The food value of mushrooms is low, as nearly 91 per cent of the flesh is water. Proteins make up 3.75 per cent, carbohydrates 3.50, and fats only 0.20 per cent.

Truffles

Truffles have been famous almost as long as mushrooms and today are considered as greater delicacies and so are higher priced. Truffles differ from most other fungi in producing their fruiting bodies underground. They are solid, with a firm black or grayish-brown flesh and an agreeable odor and taste. Truffles are common in England and on the Continent. The chief commercial area is southern France. These fungi prefer a light, porous

limestone soil in oak, beech, or birch forests. They are usually collected in the wild state, although crude attempts at cultivation have been made. These consist for the most part of stimulating natural production in favorable areas. Truffles are harvested with the aid of specially trained dogs or pigs, whose keen sense of smell enables them to locate the fungi. Truffles are collected when comparatively mature. Several species of the genus *Tuber* are utilized, chiefly *T. melanosporum*, *T. aestivum*, and *T. brumale*.

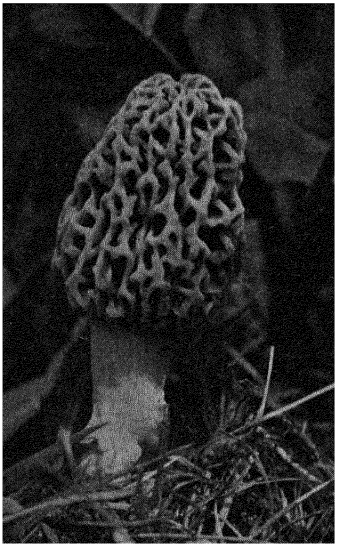


FIG. 129.—The morel (*Morchella esculenta*), an edible wild mushroom. (*Photo by D. H. Linder.*)

Other Fungi

The *morel* (*Morchella esculenta*) is a familiar wild edible fungus in the United States (Fig. 129). This species and several allied ones are grown to some extent in France, and other fungi elsewhere in Europe. In Japan, where enormous quantities of wild fungi are eaten, several native species are cultivated, chiefly the *shiitake* (*Cortinellus Berkeleyanus*). This aromatic species is grown on logs. It can be kept for a long time in a dried condition and is a favorite ingredient of soups. Over 1000 tons are grown annually.

ALGAE

Only a few species of algae are utilized in Europe and America for food purposes and seaweeds are of little economic importance. In Japan, China, and the Pacific islands, however, algae constitute one of the chief articles of diet. So great is the demand in Japan that the natural supply is insufficient and many species are cultivated. It is not unusual to find six or seven different kinds served at a single meal. Over 70 varieties are eaten in Hawaii,

and a few of these are cultivated. The nutritive value of algae is high. They have a high carbohydrate content, around 50 per cent, with small amounts of proteins and fats. Moreover, they are rich in vitamins and also contain a greater variety of mineral salts than any other food.

Only three species of algae are of any importance as sources of food in the United States. These are Irish moss, dulse, and agar.

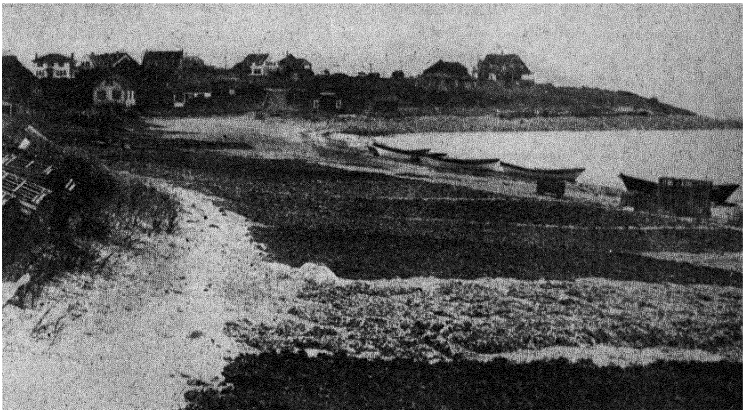


FIG. 130.—Drying and bleaching Irish moss (*Chondrus crispus*) on the beach at Scituate, Mass. (*Courtesy of the E. L. Patch Company.*)

Irish moss (*Chondrus crispus*) is a perennial species found from Maine to North Carolina. The fresh plant is greenish purple in color with densely tufted fronds from 2 to 10 in. in length. These are narrow and cylindrical at the base but soon become flattened and repeatedly forked. This species is especially common in New England and the collection of the "moss" commercially is carried on in eastern Massachusetts. The plants are gathered with iron rakes at ebb tide and are then spread out on the beach to bleach (Fig. 130). After a while they are soaked in salt water and again bleached. This process is repeated four or five times. The final commercial product is yellowish white and has a hard, horny consistency. Irish moss has a high mucilage content and is used chiefly in making blancmanges, farinas, and similar desserts. This species also grows on the Atlantic coast of Europe and is a favorite food in the west of Ireland.

Dulse (*Rhodymenia palmata*), a red alga found on rocky shores on both sides of the Atlantic, is often dried and used for food. It is sometimes marketed as "sea kale."

Agar, which has already been discussed under drug plants, is a favorite food in China and Japan, where it is used in jellies, soups, sauces, etc. In the United States and Europe it is used in making ice cream, pastries, and desserts because of its gelatinous consistency. It is also used in canning fish, clarifying liquors, and various other industrial operations.

Other species of algae, which are used in Scotland, Ireland, and Iceland for food, include the green laver (*Ulva lactuca*), pink laver (*Porphyra laciniata*), and murlins (*Alaria esculenta*).

CHAPTER XIV

THE MAJOR CEREALS

THE NATURE OF CEREALS

The cereals are without question the most important sources of plant food for man and the lower animals. This is not only true today, but has been so since earliest time. During their long period of cultivation their original wild ancestors have been lost sight of, and countless new species and varieties have been evolved. Much of this evolution occurred prior to the historical period for the older civilizations were already familiar with several kinds of wheat, barley, and other grains. Moreover, the actual origin of these useful plants had been so long forgotten that they were given supernatural powers and played a part in the religious ceremonies of the various nations of antiquity

Long before the Christian era the ancient Romans held festivals at seed time and harvest in honor of the goddess Ceres, whom they worshipped as the giver of grain. At these festivals they brought offerings of wheat and barley, the *cerealia munera*, or gifts of Ceres, a fact responsible for the modern name, "cereals." The Greeks had similar religious observations. In the New World the Mexican natives worshiped an agricultural deity to whom they brought the first fruits of their harvest. In fact, nearly every primitive race has worshiped some deity who presided over its crops.

The cereals are all members of the great grass family, *Gramineae*, and are alike in possessing the characteristic fruit of that family, the karyopsis. In this fruit the wall of the seed becomes fused with the ripening ovary wall to form the husk. The term "grain" is applied either to this type of fruit or to the plant that produces it. The true cereals are six in number: barley, maize, oats, rice, rye, and wheat. Of these wheat, maize, and rice are the most important, and each has played an important part in the development of civilization. Sometimes the millets, sorghums, and even buckwheat are erroneously referred to as cereals.

The reasons for the importance of cereals as food plants are many. One or more of these grasses are available for each kind of climate. The northern regions have barley and rye, the temperate regions wheat, and the tropics and warmer temperate areas maize and rice. Cereals also have a wide range of soil and moisture requirements. They can be cultivated with a small amount of labor, and have a large yield. The grains are easy to handle and store because of their low water content, and they are very high in food value. Cereals contain a higher percentage of carbohydrates than any other food plant, together with a considerable amount of proteins and some fat. Even vitamins are present.

WHEAT

Wheat is the chief cereal of temperate regions and so is by far of the most importance to the white race. It is very old and its native home is in doubt. Some of the more recent investigations point to the highlands of Palestine and Syria as the place of origin, although the Central Asian plateau and the Tigris and Euphrates valleys have been suggested. It has already been pointed out that Vavilov considers wheat to have had a multiple origin, the soft wheats coming from the mountains of Afghanistan and the southwestern Himalayas; the durum wheats from Abyssinia, Algeria, and Greece; and einkorn from Asia Minor. Wheat was the basis of the Babylonian civilization and it was cultivated by all the other nations of antiquity. Numerous varieties were known to Aristotle, Theophrastus, Pliny, and the other Greek and Roman writers. It was grown in China as early as 2700 B.C., and was used by the Lake Dwellers of Switzerland and Hungary who go back to the Stone Age. Wheat was first introduced into the New World in 1529 when the Spaniards took it to Mexico. Gosnold, the English explorer, sowed wheat in New England in 1602. It reached Virginia in 1611, California in 1769, and Minnesota in 1845.

Characteristics of Wheat

Wheat is an annual grass, belonging to the genus *Triticum*, which comprises a considerable number of wild as well as cultivated species. The wild forms are often troublesome as weeds, but are valueless as food plants. Cultivated wheat (*T. aestivum*)

grows to a height of from 2 to 4 ft. The inflorescence is a terminal spike or head consisting of from 15 to 20 spikelets borne on a zigzag axis. The individual spikelets are sessile and solitary and consist of from one to five flowers each. The mature grain (Fig. 4) consists of the embryo (6 per cent), a starchy endosperm (82 to 86 per cent), the nitrogenous aleurone layer (3 to 4 per cent), and the husk or bran (8 to 9 per cent) This last structure is composed of the remains of the nucellus, the integuments of the seed coat, and the ovary walls or pericarp.

Kinds of Wheat

The long period of cultivation of wheat has resulted in the production of innumerable species and varieties, as a result of the conscious or unconscious selection on the part of man of forms that possessed some particularly desirable qualities. In general eight kinds of wheat are recognized (Fig. 131). These were differentiated as species by Hackel

Triticum	*monococcum*			einkorn
	polonicum			Polish wheat
		dicoccum		emmer
		spelta		spelt
	(*satvum*)		*vulgare*	common wheat
		(*tenax*)	*compactum*	club wheat
			durum	durum wheat
			turgidum	poulard wheat

The most primitive of these species are einkorn, emmer, and spelt. Like the wild grasses of the genus, these have a fragile jointed head, which breaks during threshing, and the grain does not separate readily from its enclosing envelopes.

Einkorn.—This is also called one-grained wheat as it has only one fruit in each spikelet. It is one of the oldest of wheats, going as far back as the Stone Age. It is a plant which can utilize very poor soil and will grow where other types cannot. Einkorn is a small plant, rarely 2 ft. in height, with a very low yield. It is still cultivated to some extent in the mountainous regions of Southern Europe, especially in Spain. It is rarely used for bread, but chiefly for fodder. In the United States the plant is grown for experimental purposes only.

Emmer.—This species, also known as starch wheat, rice wheat, or two-grained spelt, has a flattened head with bristles or awns.

It is another very old type and was grown in Babylonia and by all the early Mediterranean nations and the Lake Dwellers of Europe. It is still cultivated in the mountainous parts of Spain, Italy, Switzerland, Germany, and Russia. The plant thrives in dry soil. Emmer has been introduced into the United States from Russia. It has some use for livestock and breakfast foods.

Spelt.—Spelt, another primitive wheat of antiquity, is very hardy and can be grown on the poorest soils. It has been cultivated in the Mediterranean region for centuries, and is still grown



FIG. 131.—Heads of the eight kinds of wheat. The heads from left to right are: common, club, Polish, durum, emmer, spelt, poulard, einkorn. (*Reproduced by permission from Etheridge, Field Crops, Ginn and Company.*)

in Spain. In the United States it is grown somewhat as a food for livestock.

The remaining wheats have a stout unjointed head, which does not break, and the ripe grain separates easily and cleanly.

Polish Wheat.—This plant, also known as giant rye, has a very characteristic appearance, due to the long papery bracts surrounding each spikelet. The stems are solid, and the bluish-green ears are flattened. The species is of comparatively recent origin. In spite of its name, it is not a native of Poland. It is grown chiefly in Spain, and also in Italy, Turkestan, and Abyssinia. The plants are large, but have a small yield of little value. Polish wheat has been exploited in the United States, but it is not well adapted to our conditions and gives a very unsatisfactory return.

Poulard Wheat.—This species, known also as English wheat or river wheat, is an old form, which probably originated in the dry areas of the eastern and southern Mediterranean region. The heads are large, but the yield is small and the plant is of but little importance anywhere. It has been much exploited in the United States, but has no real commercial value.

Club Wheat.—The club wheats, often called dwarf or hedgehog wheats, differ from all the other types in having short compact heads and small kernels. The plants are small and have a very stiff and strong straw. They are well adapted to poor soil and are grown chiefly in the mountainous districts of Central Europe, Turkestan, and Abyssinia. These wheats have been introduced into this hemisphere and are grown in Chili and in the Pacific and Rocky Mountain states. The grains are soft and have a low protein content, and so are not well adapted for bread making. Their chief use is for pastry flour and for export purposes.

Durum Wheat.—These wheats have thick heads with long stiff beards and large, very hard grains, which are rich in gluten. This type has been cultivated for a long time in the Old World in arid regions. It is the principal wheat in Spain, and is also grown in Algeria, India, and Russia. Durum wheats have been introduced into the United States from Russia and have proved extremely valuable. The low rainfall and high temperature, characteristic of much of the Great Plains, renders the region unsuitable for most crops. These wheats are very hardy and drought resistant and are grown with great success in this area. Because of the high gluten content, the flour is used chiefly for macaroni, semolina, and similar pastes When mixed with other flour it can be used for bread.

Common Wheat.—These common wheats are the chief source of bread flour. They occur in innumerable varieties differing in both external morphological and physiological characters. There are bearded and beardless wheats, red and white wheats, and hard and soft wheats. The hard wheats are richer in proteins and usually have small grains; the soft wheats produce large grains, which are richer in starch. The physiological characters include such features as yield per acre; lateness or earliness of maturing; resistance to drought, cold, or disease; behavior in milling and baking; and the seasonal aspect, *e.g.*, spring or winter wheat. Spring wheat is sown in the spring and harvested in late summer.

Winter wheat, on the other hand, is planted in the fall and develops a partial root system before the coming of cold weather. In the spring it has a vigorous early growth, and it is harvested in early summer. Winter wheat has a higher yield, is more resistant to disease, and matures earlier.

Grades of Wheat

The United States Department of Agriculture recognizes the following five grades or classes of wheat in its official grain standards:

Class I. Hard Red Spring Wheat.—This class comprises 24 varieties, known under 80 different names, and constitutes 20 per cent of the United States crop. These wheats are grown chiefly in Minnesota, the Dakotas, and Canada, where the winters are too severe for winter wheat, and are used for bread flour. Marquis wheat is the chief variety.

Class II. Durum Wheat.—The durum wheats are all spring wheats and include 12 varieties, of which Kubanda is the best known. They comprise about 6 per cent of the wheat crop, and are grown chiefly in the northern part of the Great Plains. They are used almost entirely for macaroni.

Class III. Hard Red Winter Wheat.—This class, with 20 varieties and 49 names, is grown chiefly in the central and southern Great Plains where hot summers and severe dry winters prevail. Kansas, Nebraska, and Oklahoma lead in production. This type of wheat constitutes 40 per cent of the total crop. Turkey, Kharkov, and Kanred wheats are the best varieties. The flour is of high bread-making quality.

Class IV. Soft Red Winter Wheat.—This class yields about 30 per cent of the wheat grown. There are 66 distinct varieties, known under 400 different names. It is the chief wheat grown east of the Mississippi River, and it is also cultivated in the Pacific Northwest. It is adapted to a more humid climate than the other wheats. The grains are more starchy, and the flour is used for pastry and home baking. This class includes the red club wheats.

Class V. White Wheat.—This class, which makes up about 5 per cent of the wheat crop, includes all the white-grained forms, whether common wheat or club wheat. The 52 varieties, grown under 170 names, include both hard and soft and spring and

winter wheats. They are grown in the Pacific Northwest and in New York state. The flour is well suited for pastry and breakfast foods, and is blended with hard-wheat flour for bread making. There is also a large export trade in this wheat.

Cultivation of Wheat

Wheat is adapted to all moderately dry temperate climates, but is not grown in warm humid regions. Areas with a growing

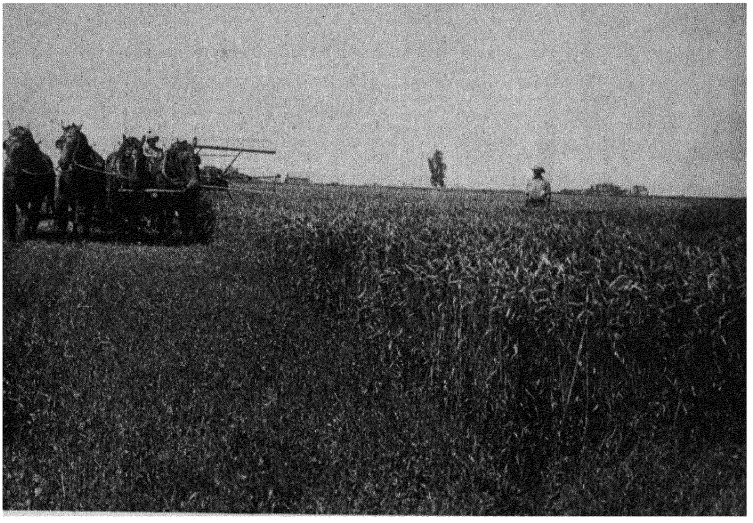


FIG. 132.—A field of Thatcher wheat growing in the Red River valley near Crookston, Minn. (*Courtesy of the Agronomy Department, University of Minnesota.*)

season of at least 90 days and an annual rainfall of not less than 9 in. are required. Over 30 in. of rain is detrimental. In general, regions with a cool moist spring merging into warm, bright, dry harvest periods are best, but the various kinds of wheat differ somewhat in their requirements. The proper climatic conditions for wheat are found in eight different areas in the world, and these are the chief wheat-producing regions. They are the plains of southern Russia and the Danube, the Mediterranean countries, Northwestern Europe, the central plains of the United States (Fig. 132) and Canada, the Columbia River basin in the Pacific Northwest, northwest India, Argentina, and Southwest Australia.

The best soils for wheat are clays and loams, although a light sandy soil can be utilized. If the ground is too wet, the plants lack vigor and produce a small yield. On the other hand, a porous soil does not hold enough moisture. Lime is an essential element and must be added if the calcium content of the soil is low. Nitrogen, phosphorus, and potassium are also necessary. The best fertilizer is barnyard manure.

The land must be thoroughly cleared, for wheat is easily choked out by weeds. Crop rotation is often practiced, and wheat is planted after a crop like beets, turnips, or tobacco, which kill out weeds. The methods of cultivation naturally vary depending on the kind of wheat and the character of the soil and climate. The time of sowing depends on whether the plant is a winter or summer annual. For a good crop the seed must be heavy, well developed, and fully ripe. Only the finest ears are used for seed. The grains are winnowed to remove dust and light grains, are then sifted and bolted, and are treated with chemicals to kill any fungus spores. Wheat may be sown broadcast, either by hand or by sowing machines, the former method being used only on small farms. On large farms two kinds of machines are used: one which sows broadcast, and the other which drills furrows and buries the seed at once. Germination begins immediately and the first leaves appear within a fortnight. In the case of spring wheat growth continues unchecked until maturity, but in winter wheat it is halted with the advent of frost. If the cold is too severe, or if the roots are exposed, winter wheat may be killed. Weeding is constantly necessary. On the largest farms machines are used which plow 24 furrows at one time. The various stages of the ripening grain are known as milk-ripe, yellow-ripe or dough, full-ripe, and dead-ripe. Wheat is not always allowed to mature fully for it is then more valuable for fodder. Wheat is attacked by several insect and fungus pests. The latter include bunt, smut, and rust. Wheat rust causes enormous losses, often wiping out a whole crop. Many attempts have been made to import rust-resistant varieties, as well as drought-resistant varieties, and also to breed them. The efforts to produce rust-resistant strains of wheat comprise one of the most thrilling stories of modern plant breeding. Although long of interest to scientists, it has recently been brought to the attention of the public in such books as "Hunger Fighters" and "Red Rust."

Harvesting of Wheat

The harvesting methods vary with the size of the farm. Simple reaping hooks, scythes, or reaping machines are used to cut the culms; and binding machines bind them into sheaves. The wheat is then housed and must be kept dry. In many parts of the world, a privilege, as old as man himself, allows the poor of

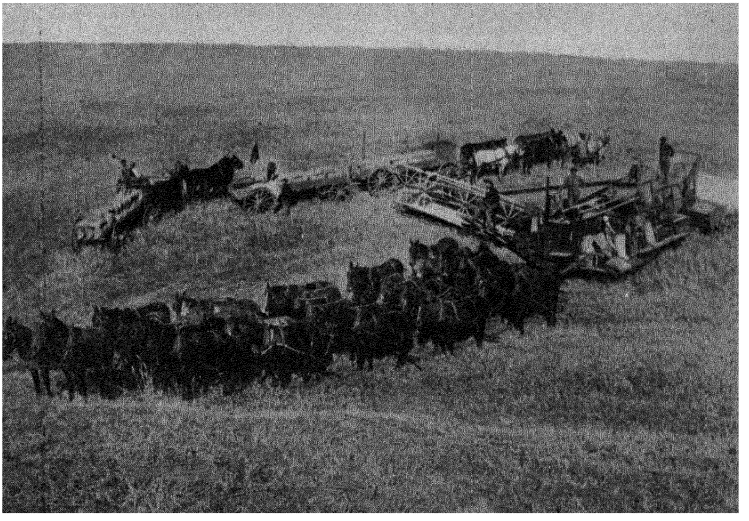


FIG. 133.—Harvesting wheat with a combine in Washington. (*Reproduced by permission of the Philadelphia Commercial Museum.*)

the neighborhood to come in and glean the ears left in the field. Threshing is the next process, and this involves the separation of the grain from the spike. This is usually done by hand, using a flail. This is a long tiresome process, but is less damaging to the grain than a threshing machine. Rows of wheat all pointing the same way are laid on the threshing floor to the depth of 1 in. These are struck at regular intervals with the flail, and then the wheat is turned and the process repeated. A cart, which traces a spiral course over the stalks, is much used in Europe. After threshing, the wheat is winnowed and sifted. Threshing machines are often used. These are either horizontal or vertical and consist of rapidly revolving drums of hard wood, provided with barbed beaters which strike the ears with great force and

with a frequency sometimes as high as 800 r.p.m. The most complicated harvesting machines have been developed on the great wheat ranches of the United States (Fig. 133). These are the *combines*, which reap, clean, thresh, winnow, and sift the grains, separate the wheat from the chaff, eliminate foreign seeds, sort into grades, and bag the grain, leaving the bags behind, and finally binding the straw. These huge portable factories are drawn by horses or tractors, and can cut a swath 40 ft. wide. It is possible with the aid of only eight men to harvest 120 acres daily.

Wheat must be stored in firmly built structures to keep out grubs and small pests, and it must be well ventilated. Buildings with a concrete wall and floor are best, although iron is much used. In the tropics subterranean silos are built. The great grain elevators at the world ports are a familiar sight. There are over 40,000 of these in the United States alone.

The Milling of Wheat

In the earliest times the grains were "brayed" between two stones; then a mortar and pestle were used, and later millstones operated by wind or water power. In most of the old mills there was a fixed lower stone upon which a movable upper one revolved. The grains were dropped into openings in the upper stone and gradually worked out between the stones, which had grinding surfaces cut in radiating lines. The whole grain was used.

Within the last 50 years the roller process of milling has been perfected. The first step in this process comprises cleaning and scouring. This consists of screening, which removes all foreign seeds, dust, sticks, straw, and pieces of bran, which might drop off later and get into the flour. The grains are then thoroughly washed and scoured. The next step is tempering. This gets the grain into the best condition for milling. A little water is added, which toughens the bran and prevents its breaking up, so that it will flake out all in one piece. Finally the conditioned and tempered wheat is submitted to breaking, grinding, and rolling. The grains are first ground between corrugated iron rollers, the so-called "first break." This cracks the grain and partially flattens it. A small amount of flour, the "break flour," is separated out by sieves, while the main portion goes to the

"second break" for more complete flattening and the partial separation of the bran and embryo. This process is repeated until five sets of rollers, each moving at a different speed, have been utilized. In each case bolting separates the ground material from the coarse bran. Eventually all the bran is removed and the purified material is passed to smooth rollers for final granulation. It is finally bolted with silk cloth, containing

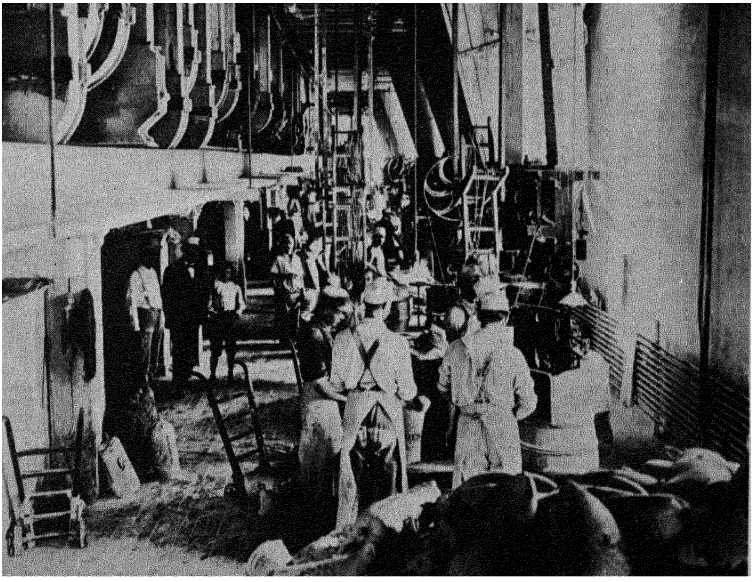


FIG. 134.—Interior of a flour mill in Minneapolis, Minn. Packing the flour for shipment. (*Reproduced by permission of the Philadelphia Commercial Museum.*)

12,000 meshes per square inch, and is then ready for packing (Fig. 134). This final product is the best grade of flour, the First Patent. Material that has been separated out is known as middlings. This may be processed and made into inferior grades of flour, or used for other purposes. Granular particles, midway in size between the grain and flour, are known as semolinas. Durum-wheat semolina is used for macaroni, and ordinary wheat semolina for farinas.

The process described above results in white flour. In the milling of graham flour the entire grain is used, while in whole-wheat flour only a part of the bran is removed.

Production and Consumption of Wheat

The world production of wheat, exclusive of Russia and China, in 1931–1932 amounted to 3,856,000,000 bu., with the United States raising one-quarter of this amount, and Kansas and North Dakota the leading states. In 1931 the domestic output was 932,221,000 bu., and over 57,000,000 acres were cultivated. For various reasons the crop was reduced by as much as 15,000,000 acres in more recent years. The 1935 figures for production, however, amounted to 603,199,000 bu., with 49,826,000 acres in cultivation. Other large wheat-producing nations are Russia, Canada, India, France, Argentina, Italy, Germany, and Australia. Of these Canada, Argentina, and Australia share with the United States in the export trade. Formerly Russia was an important exporter, but, while her production is increasing under the soviet government, her export trade has fallen off. The economic aspects of the wheat industry, both as regards domestic and international trade, are of the utmost importance, and attempts have been made by the largest wheat-growing nations to regulate the production and exportation of this, the world's most important crop.

France leads in the per capita consumption of wheat, followed by New Zealand, Australia, the United States, Great Britain, Germany, and Canada. In the United States the annual consumption of wheat is estimated at 4½ bu. per person yearly.

Wheat Products

Wheat products are probably the most widely used articles of human diet. In this country they furnish about one-fifth of the total food materials of the average family. The flour is used chiefly for making bread, and "bread" always means wheat bread. Where other cereals are used, the product is called corn bread or rye bread, etc. The hard wheats furnish bread flour, while the flour from soft wheats is used for cakes, crackers, biscuits, pastry, and similar articles. Other edible by-products are breakfast foods, like "Shredded Wheat," "Puffed Wheat," "Bran Flakes," and the various farinas; and the pastes, such as macaroni, spaghetti, and noodles. In the manufacture of macaroni, semolinas are used. These are separated from the flour and bran and mixed with 30 per cent water. The resulting dough is kneaded

and put in a hydraulic press. The dough is squeezed out through holes in the bottom. Each hole has a little pin in the center, with the result that a hollow tube of dough is formed. Strings of dough are cut into 3-ft. lengths and are dried and cured at a temperature of 70°F. Spaghetti and vermicelli are merely small types of macaroni. Noodles are made by rolling out the dough into thin strips. Durum wheat is used for macaroni, and it is grown chiefly in Russia and the United States.

Wheat is also extensively used in the manufacture of beer and other alcoholic beverages and industrial alcohol. A special kind is grown for the preparation of starch for use in the sizing of textile fibers. Wheat straw excels all other kinds because of its very great strength. It is used for seating chairs, stuffing mattresses, and the manufacture of such diverse articles as straw carpets, string, beehives, baskets, and wickerwork. Leghorn hats are straw hats made from the bearded wheat of Tuscany. Wheat straw is also used for packing and thatching and as a fodder and manure. The wheat plant is also a valuable source of fodder.

MAIZE

The Indian corn or maize plant (*Zea Mays*) is America's only contribution to the important group of the cereals. This species probably originated in a wild state in the highlands of tropical Central America. Its cultivation goes back to prehistoric time. Grains of maize found in the tombs of the Incas in Peru represent several different varieties, so that the plant must have been grown for many centuries prior even to the period of the Inca civilization. By the time that America was first visited by European voyagers maize was growing all the way from the Great Lakes and the lower St. Lawrence valley to Chili and Argentina. Introduced into Europe by Columbus, and into Asia by the earlier Portuguese explorers, maize has taken hold wherever the climate would permit and has now spread all over the world. Even under primitive conditions of agriculture large yields are possible and the plant has always been a popular one. Because of a confusion of terms, it is more desirable to use the word "maize" than "corn" in referring to this plant. In the United States "corn" always means maize, but in other countries "corn" is used for all the cereals, and may mean any hard edible seed, grain, or kernel. In England, for example, an ear of corn means a head

or spike of wheat. It was only natural that the early colonists in America should have called maize "Indian corn." Maize is known as Turkish wheat in Holland, as Spanish corn in France, Egyptian corn in Turkey, Syrian durra in Egypt, and mealies in Africa.

Characteristics of Maize

Maize is the largest of the cereals (Fig. 135), a tall annual grass attaining a height of from 3 to 15 ft. The jointed stem is solid



FIG. 135.—A field of maize (*Zea Mays*) in Connecticut. (*Courtesy of the Connecticut Agricultural Experiment Station in New Haven.*)

and contains a considerable amount of sugar when young. The leaves are large and rather narrow, with wavy margins. In addition to the extensive fibrous root system, aerial prop roots are usually formed at the base of the stem. Two kinds of flowers are produced. The tassel, at the top of the stem, bears the staminate flowers, while the cob or ear with the pistillate flowers is produced lower down on the stalk and so is protected by the leaves. Each ovary has a long silky style, the corn silk. The ovaries, and consequently the mature grains, are produced in rows on the cob. The cob is surrounded by a husk composed of leafy bracts. The grains consist of the hull (6 per cent), protein or aleurone

layer (8 to 14 per cent), endosperm (70 per cent), and embryo (11 per cent). Two kinds of endosperm are usually present: a hard, horny yellow endosperm and a soft white starchy endosperm.

Kinds of Maize

No wild species of the genus *Zea* are known today. The original ancestor has probably given rise through a process of evolution to the present-day maize plant, and its nearest relative, the teosinte (*Euchlaena mexicana*) of Mexico, as well. Maize is well adapted to breeding experiments, and even the Indians had learned how to select, produce, and preserve the best varieties, which have given rise to the easily cultivated and rapidly maturing types of today. These fall into six quite distinct classes, (Fig. 136) which breed true to type. Although they hybridize readily, there are surprisingly few intermediate types in nature. These classes, differing chiefly in the nature of the endosperm and the shape of the grain, are considered by some authorities to be species and by others to be varieties (see appendix). They include:

Pod Maize (*Zea tunicata*).—In this interesting type each grain is covered with a husk, in addition to that which covers the whole ear. The plant is exceedingly leafy and the tassels are very heavy. The grains may resemble those of any of the succeeding types, suggesting that pod maize must be very close to the primitive form from which the others have been derived. Obviously this type of maize is of no commercial value owing to the presence of the individual husks.

Pop Maize (*Zea everta*).—The grains in this type are usually elongate and oval, and, although small in size, they are very hard and flinty with a tough hull. The endosperm is mostly of the hard glossy variety. When the dry grains are exposed to a high temperature, they explode, forming a snow-white, fluffy, palatable mass. This phenomenon is called "popping" and is caused by the sudden expansion of the soft endosperm, which results in the grain's turning inside out. Several theories have been advanced to explain this. It is probably due to the expansion of the moisture content of each individual starch grain after partial hydrolysis during the heating of the grain. For a time the swelling endosperm is confined by the flinty protein layer, but eventually this breaks and the sudden release of pressure causes

the endosperm to become everted about the embryo and hull. The presence of too much white endosperm prevents popping. Two kinds of popcorn occur: rice popcorn, in which the grains are pointed and tend to be imbricated; and pearl popcorn, in which the grains are rounded and very compact. The plants produce a large number of small ears. This type of maize was probably grown in prehistoric time. Today some 25 different varieties

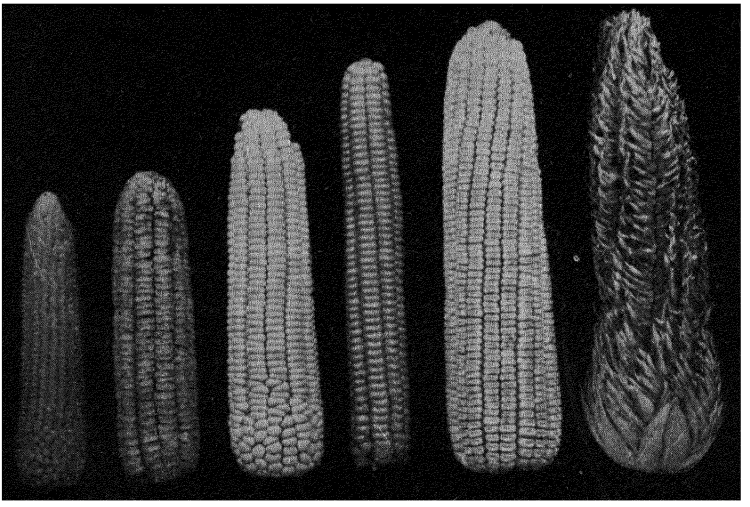


FIG. 136.—Representative ears of the six kinds of maize. From left to right the ears are: pop, sweet, soft, flint, dent, pod.

are grown for human consumption. Most of the crop is local, and there is but little commercial production.

Flint Maize (*Zea indurata*).—In flint maize the embryo and white endosperm are entirely surrounded by the hard endosperm so the grain is not dented. The plants reach a height of from 5 to 9 ft., and have a tendency to be two eared. The ears are long and cylindrical with hard smooth grains in from 8 to 16 rows. The grains are likely to be of different colors. Flint maize matures early, and so is grown in New England and adjacent areas, Wisconsin, and other Northern states. It is a very old type. Some 70 varieties are grown.

Dent Maize (*Zea indentata*).—In dent maize the white endosperm extends to the top of the grain, and the hard endosperm

is present only on the sides. This results in an indention of the mature grain at the top, due to the shrinking of the soft material. This is the largest type, the stems attaining a height of from 8 to 15 ft. The plants produce a single ear. The ears are very large, up to 10 in. in length and weighing ¾ lb., and with sometimes as many as 48 rows. The deep wedge-shaped grains are usually yellow or white. Dent maize is the principal type grown in the Corn Belt as it has an enormous yield. It is the source, not only of most of the commercial grain, but of most of the fodder and ensilage as well. About 325 varieties have been developed.

Soft Maize (*Zea amylacea*).—In soft maize the hard endosperm is entirely lacking. This type is very old and was extensively cultivated by the Indians because of the ease with which it could be crushed. The grains resemble flint maize in shape and appearance, but the size varies from small forms to the large Cuzco variety of Peru, which are ¾ in. or more in diameter. About 27 kinds are known. Soft maize matures very late in the season. It is not grown on a commercial scale in the United States.

Sweet Maize (*Zea saccharata*).—Sweet maize has the entire endosperm translucent or horny, and the starch has been more or less changed to sugar. The grains are broad and wedge-shaped with a characteristically wrinkled surface. The plant is adapted to the cooler areas, and is the chief type grown in the North Atlantic and Central States for canning purposes. The grain is used in the unripe state. Sixty-three varieties have been developed.

The Cultivation and Harvesting of Maize

Maize is distinctly a summer annual and requires very definite environmental conditions for its proper development. The best soil is a fertile, friable, well-drained alluvium, such as the deep, warm, black loams along river bottoms and in drained swamps. These soils must have a high organic and nitrogen content, and must not bake out. In addition to soil, temperature, sunshine, and moisture are limiting factors. The temperature of both the air and soil is important, especially during the growing season from May to September. A mean average summer temperature of 75°F. is the best, and it should not fall below 66°F. Sunshine is essential, and too many cloudy days are bad. Moisture is also very necessary. The optimum amount is a 20-in. annual rainfall

coming mostly in summer. A great difference in the habit of growth is correlated with different climatic conditions, and there are varieties adapted to each type. A continental climate is most favorable. The growing season of maize varies from 90 to 160 days, depending on the locality. Maize does not mature north of 50°, although it can be grown as a fodder crop beyond that latitude.



FIG. 137.—"Corn shocks" in a Connecticut field. (*Courtesy of the Connecticut Agricultural Experiment Station in New Haven.*)

Comparatively few regions in the world have the right combination of the necessary environmental conditions so that maize can be raised as a commercial crop on a large scale. The one outstanding area is the great Corn Belt of the United States, located in the Mississippi valley in the states of Illinois, Indiana, Missouri, Iowa, Kansas, and Nebraska. Here the optimum conditions for development are found: a mean summer temperature of from 70 to 80°F., with night temperatures above 58°F.; no frost for 140 days; and an annual precipitation of from 25 to 50 in., at least one-fourth of which comes in July and August.

In growing maize the fields must be well plowed and harrowed. The seed is planted to a depth of 1 to 4 in. in regularly spaced

rows. Constant weeding and hoeing are necessary, care being taken not to injure the roots. The use of fertilizers and the rotation of crops are advisable. Maize has comparatively few enemies. The corn borer is the worst insect, and corn smut is the most serious of the fungus pests. Drought, however, may cause very serious damage.

Considering the long period of cultivation, there have been very few changes in the method of harvesting (Fig. 137). On small farms the ears are husked by hand directly in the field, and then cattle are turned in to graze. On the larger farms the maize is cut with a corn knife or a machine. The stalks are stacked to permit the grain to ripen further. After a month of this curing process, the ears are husked by machine. Maize must be stored in well-ventilated bins, so that excess moisture will evaporate, and proper protection must be taken against rodents and other small pests.

Uses of Maize

The chief use of maize is as a food for livestock The grain is very nutritious, with a high percentage of easily digested carbohydrates, fats, and proteins and very few deleterious substances. The pork industry in the United States is dependent almost entirely on maize and uses about 40 per cent of the total amount raised. Cattle, horses, and other domestic animals are also fed on maize. It has been estimated that 10 to 12 lb. of corn is converted into 1 lb. of beef, while 5 or 6 lb. yields 1 lb. of pork. About 85 per cent of the maize crop is used on the farms where it is raised. Not only is the grain valuable as a stock feed, but the plant as a whole is an important fodder crop. It is used green or as *silage*. For the latter purpose the leaves and stems are cut into small pieces and placed in silos, large receptacles with airtight sides and bottoms. Here a slight fermentation takes place, and the resulting product is more palatable for cattle. *Stover*, the residue after the ears have been removed, is also fed to cattle or used for silage.

Maize is not very important as a food for man. Cornmeal is a poor breadstuff, owing to the absence of gluten, and corn bread is very crumbly and cannot be baked in loaves. The meal was first prepared by merely pounding the grain; later millstones were used, and now a milling process, involving the use of rollers, has

been substituted. The whole grain was formerly used in milling, but the fatty oil, present in the embryo, gave an unpleasant odor and taste to the meal. In modern processes the embryo and hull are removed. Both white and yellow meal are milled. Cornmeal has many uses in other countries, and in the southern United States. When boiled with water, it becomes mush, or hasty pudding, the Italian polenta. It is often baked in cakes, such as johnny cakes, ash cakes, hoe cakes, corn pone, and the Mexican tortillas. For corn bread the meal is usually mixed with wheat or rye flour. Scrapple is cornmeal that has been boiled with scraps of pork, liver, and kidney, and then seasoned and fried. Hominy or samp and hulled corn are prepared by soaking the grains in the lye of wood ashes to remove the hull, and then cooking until soft. Small portions of the hard endosperm obtained during the milling process constitute hominy grits. The grain is also used in the preparation of many breakfast foods. In the United States much corn on the cob is eaten, and sweet corn is extensively canned, the 1935 pack amounting to 515,376,000 cans.

The **industrial uses of corn and corn products** are of increasing importance. The manufacture of cornstarch and its derivatives, glucose or corn syrup, corn sugar, dextrins, and industrial alcohol; and the production and uses of corn oil, obtained from the embryo, have already been discussed. The grain is used for making various alcoholic beverages. The fibers in the stalks have been used for making paper and yarn; the pith for explosives, as a light packing material, and formerly for upholstery; the inner husks for cigarette papers, after being boiled in sugar, pressed smooth, and dried; and the cobs for fuel, smoking pork products, pipes, and as a source of charcoal. As a result of recent chemical investigations the stalks, cobs, and other waste from maize bid fair to become important sources of valuable solvents, explosives, and even a gas that can be used for home consumption.

Production of Maize

The United States normally produces over one-half of the world's supply of maize. Iowa, Nebraska, and Illinois are the leading states. In spite of the fact that its commercial production is restricted, maize has the widest range of any crop and

is grown in every state and on 75 per cent of the farms of the country. The estimated production of the world in 1932–1933, excluding Soviet Russia, was 4,824,000,000 bu., of which the United States produced 2,907,000,000 bu., grown on 108,668,000 acres. In 1935, 92,727,000 acres were harvested and 2,202,852,000 bu. were produced out of a world total of 4,090,000,000 bu. Argentina is the second largest producer, followed by Brazil, Rumania, Yugoslavia, Russia, and Italy. Considerable maize is grown in parts of Africa and Asia for local consumption.

RICE

In tropical countries rice replaces all other cereals as the staff of life. As a matter of fact rice is the principal food of over half the population of the world. This statement may seem to be extreme until we remember that the most important rice-eating countries are all densely populated. China with 400,000,000 people, India with 300,000,000, Japan with 50,000,000, and Java with 40,000,000 are only four of the countries in which the growing of rice is the chief agricultural industry.

The cultivation of rice extends back into the dim past with no authentic records as to when it began. The plant originated somewhere in Southeastern Asia, but during its long period of cultivation it has spread to every warm region of the world. The history of rice and the history of China are closely interwoven. The Chinese were the first to cultivate rice and their records go back for 4000 years. They have always considered it of great importance, and many ceremonies have arisen in connection with planting and harvesting. In classical Chinese the words for agriculture and rice culture are synonymous, indicating that rice was the staple crop at the time when the language was taking form. In other languages the words for rice and food are identical. Rice was introduced into India before the time of the Greeks, and very early reached Syria and Northern Africa. The first rice was grown in Europe in 1468 in Italy. The first rice in America was grown in South Carolina in 1694 from seed brought from Madagascar.

Characteristics of Rice

The rice plant is a large annual grass growing to a height of from 2 to 4 ft. Instead of bearing an ear, rice produces a panicle,

an inflorescence (Fig. 138) composed of a number of fine branches, each terminating in a single grain surrounded by a husk. The grains are readily detached together with this brown husk. In this condition it is known as paddy. Common rice is *Oryza sativa.* This species has developed countless varieties under



FIG. 138.—Herbarium specimen of rice (*Oryza sativa*). The inflorescence of rice is a panicle.

cultivation. There are said to be 1107 in India alone, and 1300 more in other countries. These differ in the color, shape, size, flavor, and other characteristics of the grain. One of these types contains a sugary substance instead of starch, which forms a soft, sticky, palatable mass on boiling. This plant is grown to some extent. Other species of *Oryza* occur as wild plants in the tropics of both hemispheres.

Cultivation of Rice

Rice is primarily a plant of the hot moist tropics. It prefers a climate where the average summer temperature does not go below 77°F. It grows best on damp soils underlaid with a semi-impervious subsoil in places where it can be flooded. The delta and flood plains of the monsoon region are particularly favorable. One type of rice, the upland or hill rice, can be grown like any other crop, but this is of little importance. The lowland rice, which has to be flooded during part of its development, is grown



FIG. 139.—Terraced rice paddies at Leptano, Bontoc, Philippine Islands.

almost exclusively. Rice culture in wet areas is much the same the world over. In many countries where land is cheap, primitive methods of agriculture are used. In other countries rice cultivation has had a remarkable development, and even steep hillsides are utilized by the construction of terraces (Fig. 139). The fields are plowed or hoed and the rice is sown broadcast or transplanted from seed beds when 9 or 10 in. high. The young plants are covered with water, at first only at night, but later all the time, and the water is kept in circulation. As soon as ripening starts, the water is drawn off and the field is allowed to dry out. Rice is harvested much as wheat is and the stalks are

stacked up to dry. In the United States it is possible to use machines in harvesting the crop, which greatly reduces the expense.

Milling of Rice

The grains of rice are removed by threshing or by drawing the stalks through narrow slits. When rice is to be used directly for daily consumption, it is left in the "paddy" condition, since it keeps much better. The grains are husked just before they are to be used and are then pounded in a mortar with a wooden mallet and winnowed. The resulting grain is very nutritious for it contains considerable protein and fat as well as starch.

In the commercial preparation of rice the impurities are removed and the paddy is passed between millstones to break up the husk. This chaff is removed by blowers. The grain is then pounded in huge mortars and a portion of the bran layer and embryo is removed. The waste is known as rice bran. The white rice is then scoured by friction and polished and a coating of glucose, talc, or chalk is added. During these last processes the outer, more nutritive parts of the grain are removed. The rice polish which is left as a residue is twice as nutritious as the finished product.

Uses of Rice

The chief use of rice is as a food, and more people use it than any other grain. Because of an insufficient protein content, rice should be supplemented by legumes or some other food rich in proteins. A diet of rice and soybeans constitutes the food of millions of Asiatic natives. The polished rice, which reaches the world markets, is much less nutritious, but its use is increasing. Rice hulls and rice polish are valuable as stock feed. The straw may be plaited and made into hats, shoes, and other articles. Rice starch is much used in Europe. In several tropical countries intoxicating beverages are made from rice.

Production of Rice

It is difficult to estimate the world production of rice for there are no reliable returns from China, where the crop is tremendous. The rest of the world produced in 1933–1934 about 137,000,000 lb., with India responsible for one-half this amount. Other

important countries are Japan, Indo-China, Java, Siam, Korea, the Philippine Islands, Formosa, and the United States. Rice is also grown in Egypt and other African countries, while Italy leads in European production.

In the United States rice is grown chiefly in Louisiana, Texas, California, and Arkansas. Formerly the Carolinas produced the



FIG. 140.—A field of rice in California.

best rice, but the crop has not been important since the Civil War. Louisiana, however, has developed a great industry and today produces almost one-half the total domestic crop. California has grown rice only since 1903. The heavy clay soils of the Sacramento valley have proved to be well adapted to the crop and it is of increasing importance (Fig. 140). The 1934–1935 output of rice in the United States amounted to 1,064,000 lb.

CHAPTER XV

THE MINOR CEREALS AND SMALL GRAINS

BARLEY

Barley is of great antiquity as a cultivated cereal and was used for bread even before wheat. Pliny claimed that it was man's most ancient foodstuff. It was known to all the ancient civilizations of the Old World, and the Lake Dwellers of Europe were familiar with no less than three kinds. Barley, according to Vavilov, probably originated in Southwestern Asia, Northern Africa, and also in Southeastern Asia.

Barley is an annual plant, tending to become perennial. It is related to wheat and resembles the latter in many respects. It seldom reaches more than 3 ft. in height (Fig. 141). The inflorescence is a dense head with three sessile spikelets alternating at each joint of the straight axis. Most barleys are conspicuously bearded, though some are naked. The grains, which are often colored, remain enclosed in a husk formed by the subtending scales. The structure of the grain is similar to that of the other cereals.

The genus *Hordeum*, to which barley belongs, contains about 20 species, mostly weeds of temperate regions. As in the case of other plants that have been cultivated for centuries, there are a great number of present-day forms of our cultigen, *H. vulgare*. The classification of these different species, or varieties, of barley is particularly difficult, and no two authorities agree on all points. However, there seem to be two well-defined groups, the six-rowed forms and the two-rowed forms. In the former (*H. hexastichon*), all the spikelets are fertile. In the latter (*H. distichon*), the lateral spikelets are sterile, so that only two rows develop. The ancestor of barley may have belonged to either of these two types.

Barley is very hardy and has a short growing season so it can be grown at high altitudes and latitudes. It is grown in the Rocky Mountains at an altitude of 7500 ft. and in the Andes

at 11,000 ft. In Alaska it reaches a latitude of 65°N.L., while in Russia it is grown up to the shores of the Arctic Ocean. Barley, however, is not confined to cold regions, for it is an important crop in France, Turkey, and even semitropical California. Both winter and spring barley are grown.

Until the sixteenth century barley was the principal source of bread flour, and it has remained a staple food in Northern countries until comparatively recently. In the most prosperous



FIG. 141.—Harvesting winter barley with a cradle.

countries it has now been supplanted by the more palatable wheat. The nutritive value of barley is considerable, though a deficiency in gluten makes it a poor breadstuff. Unleavened barley cakes, however, are a favorite food of the rural classes in Scotland and other Northern countries. The husk is ground off, yielding pot barley, and, if more of the grain is ground, the familiar pearl barley results. This is much used for soups. Barley is also used for breakfast foods and children's food. The six-rowed kinds, which have a higher protein content, are used for food purposes, both for man and for animals.

The chief utilization of barley today is as a source of malt to be used for beer and similar beverages and various malt extracts.

For this purpose the two-rowed types, with a low protein content, a mealy endosperm, and thin hull, are preferable. The preparation and use of malt will be discussed later. Barley is also used for hay and pasturage and as a smother crop to kill out weeds. The straw is used for stock feed and bedding.

Russia usually leads the world in the production of barley, with the United States or Germany as its closest competitor.



FIG. 142.—A field of rye (*Secale cereale*) in South Carolina.

The 1932 production in the United States was 302,000,000 bu., while in 1935–1936 it amounted to 292,000,000 bu. The northeastern section grows the six-rowed kind, the Northwest the two-rowed, and the rest of the country both kinds. Minnesota and the Dakotas are the leading states. India, Spain, Canada, and Japan are also important producers of barley.

RYE

Rye (*Secale cereale*) is of more recent origin than the other cereals. *S. montanum*, a wild species of Afghanistan and Turkestan, is thought by some authorities to be the wild ancestor. In any event rye is probably a native of the Black and Caspian Seas region of Central Eurasia. It has been cultivated for a much shorter time than the other cereals. There are no traces of it

among the ruins of Egypt or the Lake Dwellings, although the plant was known to the Greeks and Romans.

Rye (Fig. 142) is related to both barley and wheat, and resembles the former in habit; its grain looks like that of wheat. The stalks are slender and tough, reaching a height up to 6 ft. The leaves are somewhat bluish. The heads consist of a large number of spikelets, which are produced singly at the joints of the axis, and each one contains two fertile flowers. The grains have a normal structure. Rye is a very constant plant, and there are only a few varieties.

Rye will produce satisfactory crops in regions of severe winter temperatures and at high altitudes. It does well on poor soil and in arid areas, and has been called the "grain of poverty." In spite of this, rye thrives best on more fertile soil.

Rye is primarily a plant of Europe, where 96 per cent of the world's crop is produced and consumed. It is used there chiefly for bread, as the grain contains gluten. Rye bread, known as *schwartzbrot* or black bread, is dark colored and soggy and has a bitter flavor. Until the middle of the last century it was the chief food of a third of Europe's population.

Rye is also used for hay and pasturage, as a winter cover to prevent erosion and leaching, as a sand binder, and in crop rotation. The straw is valuable, for it is very tough, and is in demand for bedding, packing purposes, and the manufacture of paper and various other straw products. The grain is used for stock feed and as a source of whisky and alcohol. Russia has long been the chief producing country, even when only primitive methods of cultivation and harvesting were in vogue. Germany, Poland, and Czechoslovakia also produce large amounts. In the United States rye is ordinarily of little importance, the production in 1932 amounting to about 40,000,000 bu. The 1935–1936 output, however, had increased to 58,000,000 bu.; North Dakota, Minnesota, and South Dakota are the leading states. Two-thirds of the crop is fed to animals and the remainder is used for flour, whisky, or alcohol. With us rye flour is mixed with wheat for breadmaking. In some years considerable amounts are exported.

OATS

The oat plant (*Avena sativa*) has never been found in a wild state, although it frequently escapes from cultivation and

becomes established with such ease that it may appear wild. Consequently it is difficult to determine the native home of oats or the wild ancestor. Oats probably had a multiple origin, some coming from Abyssinia, others from the Mediterranean area, and still another from China. They were grown by the Lake Dwellers,



FIG. 143.—Heads of oats (*Avena sativa*) showing types with a spreading and with a one-sided panicle. (*Reproduced from U.S.D.A. Farmers' Bulletin* 424, *Oats: Growing the Crop.*)

though not by the early Mediterranean nations. There are several wild species of *Avena*, one of which, *A. fatua*, may be the ancestor of the cultivated forms.

Oats vary in height from 2 to 5 ft. The leaves are abundant and bluish green in color. The inflorescence is a one-sided or spreading panicle (Fig. 143) which may be either erect or droop-

ing. The panicles contain some 75 spikelets, which are two- to many-flowered and which are protected by long pendant outer scales. The grain, which is surrounded by a hull formed by the inner scales, except in the so-called naked varieties, contains two aleurone layers.

Several species of oats are cultivated. The most important is *Avena sativa.* This species is quite variable and has been much improved by breeding and selection. Other cultivated forms are the Hungarian or Turkish oat (*A. orientalis*), the naked oat (*A. nuda*), and the short oat (*A. brevis*).

Both spring and winter oats are grown, the latter in regions of mild winters, such as California and the Mediterranean area Spring oats are best adapted to cool moist climates, such as occur in Northern Europe and the northeastern United States. Oats can be grown with profit farther north than any other cereal except rye. They reach a latitude of 69°F. in Alaska and 65°F. in Norway. An island climate is particularly favorable. In Scotland a third of all the cultivated land is devoted to this crop, and in Ireland half the land. Oats prefer heavy soils, but they can be grown on any tillable soil, even poor and exhausted ones. They have a high water requirement and so are not profitable in regions of high temperature unless plenty of water is available. Drought often causes great damage.

Oats are sown broadcast and are cultivated and harrowed. They are often planted with other crops. They may be harvested when the leaves are still green and when the grain is not fully ripe. The quality is improved by stacking and capping the stalks. Oats are cut, like hay, with a scythe or a machine.

Oats are the most nutritious of all cereals for human use as they have a high fat and protein content. Oatmeal has long been popular. It is a good food for muscle building, and because of its high energy content is especially well adapted for use in cold weather, and by people who lead an active outdoor life. The protein material does not occur in the form of gluten, so oatmeal is not a good bread flour. It is used chiefly in cakes, biscuits, and breakfast food. Oatmeal is prepared by grinding the grains rather coarsely between stones. The more popular rolled oats are made more carefully. Grains are thoroughly cleaned and kiln dried, and are then graded by size and run through millstones which grind off the husk. After the pieces of husk have been

removed by suction, the groats, as they are called, are softened and crushed by rollers in steam chests.

Oats constitute the chief grain food for horses, and may be used for any other domestic animal except pigs. Over 70 per cent of the domestic crop is used directly on the farms where it is produced. Oats are also grown for hay or green forage, and are frequently used in crop rotation or as nurse plants.

The United States usually leads the world in the production of oats. Few plants are more widely grown and the area of cultivation is increasing. In 1934–1935, 1,195,000,000 bu. were produced. Iowa, Illinois, and Minnesota lead, although oats are grown in every state in the union. Russia, which sometimes outstrips the United States, Germany, Canada, and France are important oat-producing countries.

THE SMALL GRAINS

Sorghum

The sorghums include a large number of widely cultivated grasses, known under a confusing variety of common and scientific names. These plants were among the first of the wild species to be domesticated by man. Sorghum was grown in Egypt prior to 2200 B.C., and has continued to be an important crop in that country ever since. It was cultivated in China and India at an early date. From their native home in Africa and Asia the sorghums have been dispersed to all warm countries, in temperate regions as well as in the tropics. Although somewhat less nutritious than maize, they constitute a staple food for millions of native peoples in Africa and Asia. Sorghums are also used for stock feed and forage; in the manufacture of brushes, syrup, and paper; and in the Orient for many other purposes.

The plants are tall coarse annuals, growing to a height of from 3 to 15 ft., and resembling maize in habit. The inflorescence is a dense head or panicle, and the grains are smaller and rounder than those of the true cereals. The root system is shallow and twice as extensive as that of maize, and the leaf area is only half as great. These facts, together with the highly absorptive nature of the roots and the ability of the leaves to roll up in dry weather, enable the plants to withstand a great amount of heat and consequent evaporation. Their low water requirement renders

them exceedingly drought resistant, so that they are well adapted to semiarid and arid regions where maize will not grow.

In the United States the cultivated sorghums are usually referred to a single species, *Sorghum vulgare*, which has also been known as *Andropogon Sorghum* and *Holcus Sorghum*. Elsewhere many of the varieties are likely to be considered as distinct species. Four types of sorghum are grown in this country. These include the grass sorghums, such as the Sudan grass (var. *sudanensis*), used entirely for hay and pasturage; the broomcorns, used in the manufacture of brushes; the sweet or saccharine sorghums, used for forage and making syrup; and the grain or nonsaccharine sorghums, which are cultivated for the grain and to some extent for forage. There is some evidence that both the sweet and grain sorghums were known to the early colonists, but the plants failed to become established. They have, however, become increasingly important since the middle of the last century and today rank in seventh place among American crops.

Broomcorn

In the broomcorn (var. *technicum*) the stems are dry and the inflorescence is a long, loose, much-branched panicle (Fig. 18) with a short axis. The spikelets are small and produce reddish-brown seeds. The use of the elongated branches of the panicle in the manufacture of brushes and brooms has already been discussed. The broomcorn was probably derived by selection from a sweet sorghum. It has been cultivated in Italy, Hungary, and other European countries for centuries, and has been grown in the United States since 1797. At the present time the greatest acreage is in Oklahoma, Kansas, and Texas.

Sweet Sorghums

The sweet sorghums (var. *saccharatum*), or sorgos as they are usually termed, are tall leafy plants with an abundant sweet juice. Their utilization as a source of syrup has been referred to. They are also extensively used for forage and silage. The black amber sorgos are of Chinese origin and were introduced into the United States in 1853 from France. The other types, prominent among which are sumac, gooseneck, and orange, originated in South Africa and were brought into the Carolinas and Georgia from Natal in 1857. Although fairly widely cultivated, sorgos

are most important in the Great Plains and Gulf States areas. Sumac is the leading variety.

Grain Sorghums

The grain sorghums are more stocky than the sweet sorghums and have a dry or only slightly juicy pith. Their commercial production in the United States dates from 1874 when durra was introduced. This was followed by kafir in 1876, milo in 1880–1885, shallu in 1890, the kaoliangs from 1898–1910, feterita in 1906 and 1908, and hegari in 1908. Today over 40 different kinds are grown, including many hybrids. These sorghums are particularly well adapted to the arid conditions of soil and climate which prevail in the southern Great Plains and parts of the Southwest. In 1935, 103,494,000 bu. were produced, principally in Texas, Oklahoma, and Kansas. The grain is fed to all kinds of livestock, and the plants are also used for forage. In other countries these sorghums furnish food for man, as well as for other animals, and have many industrial uses as well.

Durra.—The durras are the chief type of grain sorghum in Northern Africa, Southwestern Asia, and parts of India, and millions of acres are cultivated. They are of comparatively little importance in this country, however. The plants have dry stems; compact, goosenecked, bearded heads; and flattened seeds; they mature early. The classification of this group has been especially chaotic for milo, feterita, and other forms have often been included. The three forms grown in the United States at present probably represent two distinct varieties. The white durra (var. *cernuum*) was at one time very popular and was grown under the name of Egyptian corn or Jerusalem corn. The plant is still grown in California where the seeds are a favorite poultry feed. A dwarf form is somewhat more in demand. The brown durra (var. *durra*) is also grown to some extent in California.

Kafir (var. *caffrorum*).—Kafir corn, as it is often called, is a native of tropical Africa but has spread all over the world. It is an important food plant and many forms are grown. Its peculiar and characteristic flavor is not appreciated in this country, but it is highly nutritious and is similar to maize in composition and digestibility. The kafirs are stout, stocky plants from 4 to 7 ft. in height. The leafy stems have a slightly acid juicy pith, and so are valuable for forage. The inflorescences are

long, slender, cylindrical, beardless heads, which produce small, oval, white or colored seeds that are late in maturing. Some 12 varieties of kafir are grown in the United States, with Kansas, Texas, and Oklahoma the leading states. Standard Blackhull kafir is the most important of all the grain sorghums.

Milo (var. *subglabrescens*).—The milos (Fig. 144), also of African origin, have slightly juicy stems; compact, usually



FIG. 144.—A field of milo (*Sorghum vulgare* var. *subglabrescens*) in Texas. The plants are from 4 to 5 ft. in height. (*Reproduced from U.S.D.A. Farmers' Bulletin* 322, *Milo as a Dry-Land Grain Crop.*)

bearded heads, which are usually recurved or goosenecked; and large soft yellow or white seeds. They sucker very freely. The plants are very adaptable to moisture conditions and respond readily to irrigation. Although very drought resistant and able to produce some crop even under severe conditions, the yield is unusually large when conditions are favorable. Dwarf yellow milo ranks second in importance among the grain sorghums. About 12 kinds of milo are grown. The plants mature rather late but earlier than kafir.

Shallu (var. *Roxburghii*).—This distinctive late-maturing sorghum was introduced from India, where it is extensively grown as a winter crop. It has tall, dry, slender stems and long open panicles. The small, hard, white seeds are exposed at maturity. Shallu is grown to some extent in the Gulf States.

Kaoliang (var. *nervosum*).—The kaoliangs are Chinese sorghums, and constitute one of the oldest and most important crops in that country. They have furnished grain, sugar, and forage for thousands of years, and all parts of the plant have some economic value. They have dry slender stalks with but few leaves, loose or compact erect heads, and small brown or white seeds. Although they mature early and so can be grown farther north than the other grain sorghums, and although they are very drought resistant, the yield is low and they have never become popular in the United States.

Feterita (var. *caudatum*).—Feterita, an importation from the Sudan, has dry stalks; erect, compact, oval heads; and very large, soft, white seeds. It matures early and produces a crop in seasons with a limited amount of moisture. Three kinds are grown, chiefly in Kansas and Texas.

Hegari.—This sorghum is probably a form of kafir. It produces leafy juicy stems which sucker freely, and in other respects it seems to be intermediate between kafir and feterita. Hegari is very variable as to time of maturity and yield. It is grown in Texas, Arizona, and New Mexico.

Millets

The term "millet" is loosely applied to a large number of cultivated grasses with very small seeds. The millets are used for forage and as a food for both man and domestic animals. The real importance of millet is not appreciated in the United States or Europe, but fully one-third of the world's population uses these grains as a regular article of food. In India over 40,000,000 acres are cultivated and the crop is comparable in importance to wheat in the United States. Japan produces 35,000,000 bu. annually. The plants have abundant foliage and are much used for forage. Millets are very drought resistant and are extensively grown in the Great Plains area. They are sensitive to cold and cannot be planted until all danger of frost has passed. In the United States millets are used chiefly as hay crops, pasturage, and for birdseed, although some varieties are used for grain. Millets are among the most ancient of food grains, and have been grown in China since 2800 B.C. They probably originated in Eastern Asia. The most important cultivated varieties include:

Foxtail Millet (*Setaria italica*).—Some dozen varieties of foxtail millets are grown, and these are very likely to occur spontaneously as weeds. They are known by many different names, such as Italian, German, Hungarian, and Siberian millet. The plants are smaller than in the other cultivated grasses and have a dense spike for an inflorescence, with innumerable long or short bristles. In one group the heads are short, thick, and erect; in another they are long and drooping. The origin of these millets is in doubt, although some authorities are inclined to the belief that they have been derived from *S. viridis*, a common wild grass of the Old World. The native home was probably Eastern Asia, and not Europe as the common names of the plant would seem to indicate. Millet must have been domesticated in the Orient ages ago, for it was one of the five sacred Chinese plants as early as 2700 B.C. Millet seeds abound in the Lake Dwellings, but the plant was apparently unknown in Syria and Greece. At the present time the foxtail millets are extensively grown in Japan, China, India, the East Indies, and other parts of Asia; in temperate Europe; in North Africa; and in Canada and the United States. They are used for human food everywhere, except in North America, and are also an important forage crop. When used for food, the grains are boiled or parched. Millet is an important hay crop, and is good for silage. It is much used in crop rotation, and as a supplementary or catch crop after some other crop has failed. This is possible because of the rapidity with which it matures, only 6 to 10 weeks being necessary.

Several millets belong to the genus *Echinochloa*. The **Japanese or sanwa millet** (*E. frumentacea*), an erect awnless species with turgid purplish seeds, is much cultivated. It is used in the United States entirely as a forage crop, and is very desirable for it produces as many as eight crops a year and has a large leaf area. In the Orient it serves as a food plant and is eaten as a porridge or with rice. In Japan it is cultivated in areas where rice will not grow. A smaller species, the **shama millet** (*E. colona*), is another valuable forage and food crop, particularly in the East Indies and India. It is a favorite food of laborers, and is eaten by the Hindus on fast days. The common **barnyard millet** (*E. crus-galli*), which occurs with us as a weed, is cultivated in India and the Far East as a forage and food crop under the name "bharti."

Proso Millet (*Panicum miliaceum*).—This is the true millet, the *milium* of the Romans. It is also known as broomcorn millet, hog millet, Russian millet, and Indian millet. Its native home was probably India or the eastern Mediterranean region. It has been cultivated in Europe for a long time, and was largely used by the Lake Dwellers. The plant grows to a height of 2 or 3 ft., with an open, branching, compact or one-sided panicle (Fig. 145). The grains are variously colored and are closely surrounded by the scales of the spikelet This millet is extensively grown in

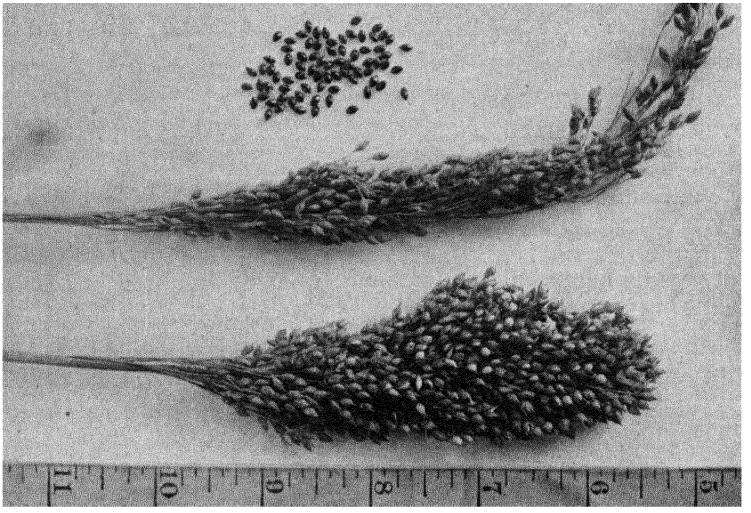


FIG 145. The grains and heads of Proso millet (*Panicum miliaceum*)

Russia, where 80,000,000 bu are produced each year. China, Japan, India, and Southern Europe also produce large amounts. Proso millet was introduced into the United States many years ago, but was grown only in the Northwest. Recently there has been a great revival of interest in the plant, and it is now extensively cultivated in the northern prairie and Great Plains regions Although of some value as a hay crop, its greatest use is as a forage grain as it is very nutritious. In addition to carbohydrates, the grains contain 10 per cent protein and 4 per cent fat. It is an excellent hog feed, and is much used as a substitute for maize or sorghum. A palatable bread can be made from fresh grains. The plant is of no value as a hay crop.

Pearl Millet (*Pennisetum glaucum*).—This is a tall plant, growing from 6 to 15 ft. in height, with three to eight compact cylindrical spikes that bear white grains. Pearl millet is grown in India, Egypt, and Africa as a rainy-season crop. It furnishes an important food for the lower classes, and is particularly valuable in cold weather because of its heating qualities. The flour made from this millet is very nutritious and is used for bread or cake. It has an enormous yield of forage, which is succulent when young, and it can be cut several times in a season. Pearl millet has been introduced into the United States as a forage crop. The wild form of the plant is unknown.

Ragi (*Eleusine coracana*).—This tall grass, which is also known as finger millet, African millet, or korakan, has tufted stems, each with four to six spikes. Both upland and irrigated forms are grown from Dutch Malaya to Northern Africa. Ragi has an exceedingly heavy yield, sometimes as much as 1500 lb. to the acre. Even on poor soil the yield is abundant. It is one of India's major crops, particularly during the rainy season, and is an important food. The grain is free from insects and can be stored for a long time. Ragi flour is used for puddings and cakes, and a fermented beverage is made from the grain. New and improved varieties are being developed by the Indian Agricultural Department.

OTHER GRAINS

Wild Rice

Wild rice is the only edible grain used in the United States which is not cultivated. The supply is obtained from wild plants of *Zizania aquatica* and the variety *angustifolia*. These tall annual grasses (Fig. 146) grow partially submerged along the margins of lakes and sluggish streams inland, and even in brackish areas along the coast, oftentimes covering hundreds of acres. Formerly an important food of the eastern Indians, wild rice is still used by the tribes of the Great Lakes and upper Mississippi valley region. The grains are borne in slender panicles and drop off very readily when mature. The Indians continue to use primitive methods of gathering the crop. Just before the grains are fully ripe, they push their canoes in among the plants and beat off the grains into the bottom of the canoe with a stick.

Later the grains are dried in the sun or over fires, and the husk is pounded or charred off. Wild rice is very nutritious and palatable and is often served with fowl and game. It can be obtained in the markets of the larger cities, although the Indians only sell what they cannot use themselves. Wild rice also serves as one



FIG. 146.—Wild rice (*Zizania aquatica*) in flower at the Arlington Experimental Farm, Virginia. (*Reproduced from U.S.D.A. Department Circular* 229, *Wild Rice.*)

of the most important foods for ducks and other waterfowl. Attempts have been made to plant the grass in the great coastal swamps. The seeds, however, are easily killed and germinate only if they have been constantly kept under water. Wild rice occurs both in eastern North America and in Western Asia. In the latter area the young stems and leaves are used as a vegetable and the straw is used for paper.

Job's-tears

This grass, *Coix Lachryma-Jobi*, is a native of Southeastern Asia, but is cultivated in nearly all tropical countries. It has large, shining, pear-shaped fruits (Fig. 147), which bear a fanciful resemblance to tears. These grains are used as food by the poorer classes, and are also said to have medicinal properties. Some varieties, especially the Philippine adlay, are good for forage. The chief use of the fruits is for ornamental purposes,



FIG. 147.—The inflorescence of Job's-tears (*Coix Lachryma-Jobi*). (*Photo by W. H. Weston, Jr.*)

and they are made up into necklaces, mats, rosaries, etc. A wholesome beer can also be made from them.

PSEUDO CEREALS

In various parts of the world many other plants are used in a manner similar to the cereals and smaller grains as sources of human food. For this reason, even though they are not grasses, they are often erroneously referred to as cereals. Two of the most important of these are buckwheat and quinoa.

Buckwheat

Buckwheat (*Fagopyrum esculentum*) is a native of Central Asia and still grows wild in Manchuria and Siberia. As compared with

most of the cereals, it is of recent use, the earliest records occurring in Chinese writings of the tenth and eleventh centuries. Buckwheat was introduced into Europe during the Middle Ages, and was first cultivated in 1436. It is widely used on the Continent, especially in Russia, where it constitutes one of the chief foods of the peasants, and over 5,000,000 acres are cultivated. France and Germany also raise a large crop. It was brought into the United States by the early settlers, and is now widely grown



FIG. 148.—A field of buckwheat (*Fagopyrum esculentum*) in blossom.

(Fig. 148). Buckwheat is normally a plant of cool, moist, temperate regions and thrives best in a sandy well-drained soil. However, it will grow in dry and arid regions and areas with very poor soil and drainage. The plant is a small branching annual. The stems are smooth and succulent with alternate hastate leaves. The inflorescence is a raceme bearing small white or pinkish flowers. The fruit is a three-cornered achene that resembles a beechnut, hence the name *buchweizen*. The seeds, or groats, are hulled and ground and the starchy flour is used for porridge, soups, and in this country for pancakes. The whole grains, middlings, or flour are also fed to livestock and poultry,

and the straw is used for feed and bedding. Buckwheat is also grown as a fertilizer crop and catch crop; the flowers are an important source of honey. Pennsylvania and New York are the chief producers of buckwheat. The crop is planted late in the spring, so as to avoid frosts, and harvested in August and September.

Quinoa

Quinoa (*Chenopodium Quinoa*) is the staple food of millions of South American natives. The plant is an annual herb, which grows to a height of 4 to 6 ft. and resembles the common pigweed. It is a native of Peru, and was used in great quantities by the ancient Incas. The Spanish explorers found nearly all the nations using it. At present it is grown chiefly in New Granada, Peru, and Chili, where it is cultivated at altitudes up to 13,000 ft. The plants produce a large crop of white, red, or black seeds, which mature in 5 or 6 months. They are very nutritious, containing 38 per cent starch, 5 per cent sugar, 19 per cent protein, and 5 per cent fat. Whole seeds are used in soups, or are ground into flour which is made into bread or cakes. The seeds are also used in making beer, in medicine, and as a poultry feed. The ash is often mixed with coca leaves to give more flavor to the latter. Quinoa has been introduced into the United States, where the thin leaves are used as a substitute for spinach.

CHAPTER XVI

LEGUMES AND NUTS

LEGUMES

Legumes are next in importance to cereals as sources of human food. They contain more protein material than any other vegetable product, and so are nearer to animal flesh in food value.

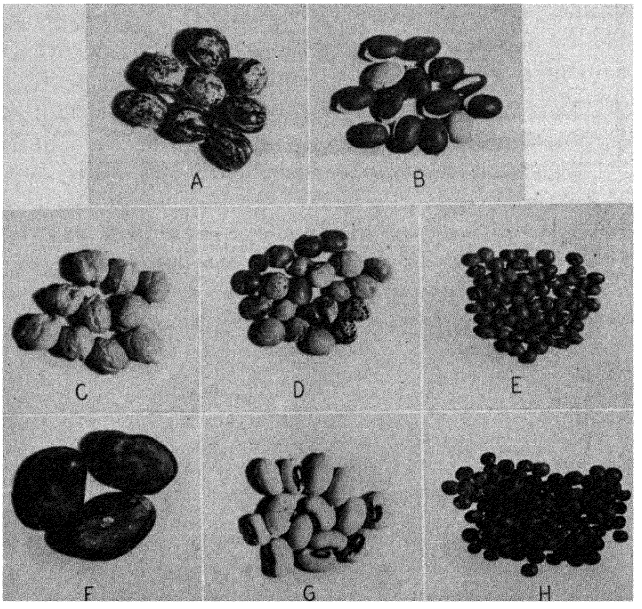


FIG. 149.—Edible seeds of various legumes. *A*, velvet bean (*Stizolobium Deeringianum*); *B*, lablab (*Dolichos Lablab*); *C*, chick pea (*Cicer arietinum*), *D*, cajan pea (*Cajanus Cajan*); *E*, mung bean (*Phaseolus aureus*); *F*, broad bean (*Vicia Faba*); *G*, cowpea (*Vigna sinensis*); *H*, lentil (*Lens esculenta*).

Carbohydrates and fats are also present. The proteins occur as small granules in the same cells with the starch grains. The high protein content is correlated with the presence, on the roots of many legumes, of tubercles that contain nitrogen-fixing bacteria. These bacteria are able to utilize free atmospheric nitrogen and

convert it into nitrates, thus augmenting the supply of nitrogenous material available for the plants.

The legumes or pulses all belong to the great family *Leguminosae*, which is characterized by having a special kind of fruit, a legume, which is a pod that opens along two sutures when the seeds are ripe. Nearly 11,000 species of legumes are known, and many are of importance as industrial, medicinal, or food plants. They have been cultivated and used for food for centuries all over the world. The seeds (Fig. 149) are of greatest importance; as in the case of the other dry seeds, the low water content and impervious seed coats enhance their value for storage purposes and increase their longevity. Legumes are easily grown, mature rapidly, and are highly nutritious. Indeed they are an absolute necessity in countries where little meat is eaten. Before the advent of the potato, they constituted a great part of the food of the poorer classes in Europe. Legumes have a high energy content and are particularly well adapted for use in cold weather or where physical exertion is involved. The immature fruits also serve as a food

Owing to the fact that not only the seeds but all other parts of the plant are rich in protein, legumes are very valuable as field and forage crops. When plowed under they are an excellent fertilizer and greatly increase the nitrogenous content of the soil.

Peas

The common pea (*Pisum sativum*) is a native of Southern Europe and has been cultivated since before the beginning of the Christian era. Peas were well known to the Greeks and Romans. Although an old crop, they were not grown in Europe to any great extent until the middle of the seventeenth century. Peas are annual, glaucous, tendril-bearing, climbing or trailing plants, with white or colored flowers and pendulous pods (Fig. 150). Although natives of warm regions, they thrive where there is a cool summer temperature and abundant moisture. Canada and the northern United States are particularly well suited to pea growing. Ontario alone has produced over 14,000,000 bu. annually. There are two groups of peas:

Field Peas.—These may have originated from the gray pea, which still grows wild in Greece and the Levant. They have colored flowers and angular colored seeds, and are very hardy,

withstanding frost and altitudes up to 8000 ft. Field peas are grown for the seed, which is used for human consumption in the form of pea meal or split peas. They are also unexcelled as part of the grain ration for livestock. They are used for forage and green manuring.

Garden Peas.—These have white flowers and round smooth or wrinkled seeds, which are yellow or white in color. They contain

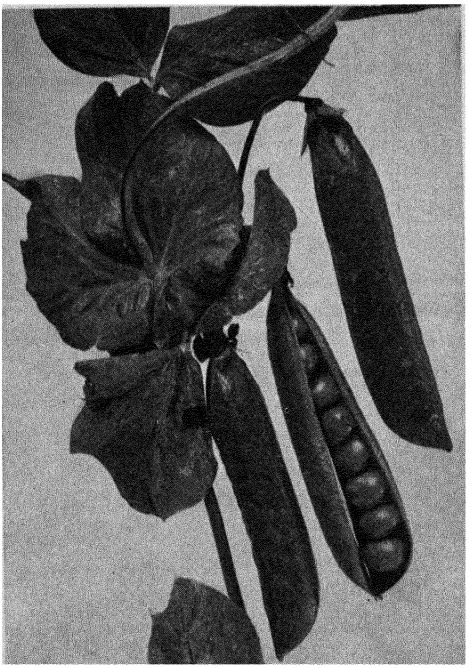


FIG. 150.—Early Morn, a variety of garden pea (*Pisum sativum*). (*Courtesy of Breck and Company.*)

more sugar than do field peas, and the seeds are eaten green or are used for canning, a great industry in the United States. In 1935, 590,736,000 cans were packed. In one type the pods are fleshy and crisp and can be eaten as well as the seeds. Garden peas are famous as the plants with which Gregor Mendel carried on his epoch-making experiments in plant breeding.

Chick Peas

The chick pea (*Cicer arietinum*) is a native of Southern Europe, where it is still extensively grown. It is also an important food

plant in many parts of Asia, Africa, and Central America although but little used in the United States. India grows an amount equal to the sugar cane acreage of the whole world, and the crop is valued at $100,000,000. The plant is a branching, bushy annual, which matures in 90 days. It is well adapted to arid and semiarid regions. The chick pea is one of the best legumes for human consumption as the seeds (Fig. 149, *C*) are very nutritious. It has been cultivated for a long time and was known to the Egyptians, Hebrews, and Greeks. The sparse foliage is poisonous so the plant cannot be used for forage. The green pods are sometimes eaten, and the seeds are used as a substitute for and as an adulterant of coffee.

Beans

The common field, garden, or kidney beans (*Phaseolus vulgaris*) are natives of the New World. They were probably domesticated by the Incas, and were early used by the Indians of both South and North America. Today the young pods (string beans), the unripe seeds (shell beans), and the dried ripe seeds are all used for human consumption, while the whole plant is used for forage. Beans are low, erect, or twining annuals with small white or colored flowers, trifoliate leaves, and slender pods (Fig. 151). They are grown as either bush or pole beans, and over a thousand varieties are cultivated. The commercial dried bean is of recent origin. It was first grown in 1836 in New York, when 1 pt. was raised. Today over 23,000,000 bu. are produced, chiefly in Michigan, California, Idaho, and Colorado. Much of the crop is canned. Although beans will grow on a great variety of soils, a fertile soil, rich in lime, is necessary for a good yield. A cool climate is desirable, and crop rotation should be practiced. On large farms the crop is harvested by machines and the beans are dried, stored, and threshed before marketing. The culls are fed to livestock and the straw is used for forage. These beans were unknown in Europe until after the discovery of America. They are now grown extensively there under the name "haricots."

Other commonly cultivated species of beans include the lima beans (*Phaseolus lunatus*), which require higher temperatures; the scarlet runner beans (*P. multiflorus*), and the mung beans (*P. aureus*). The latter plant is one of the very ancient legumes of India and is still an important crop. The small oval seeds (Fig.

149, *E*) are highly nutritious, and the green pods are also eaten. Over a hundred kinds are grown in China, and other Asiatic countries, and the crop is of increasing importance in the United States, as a forage plant.

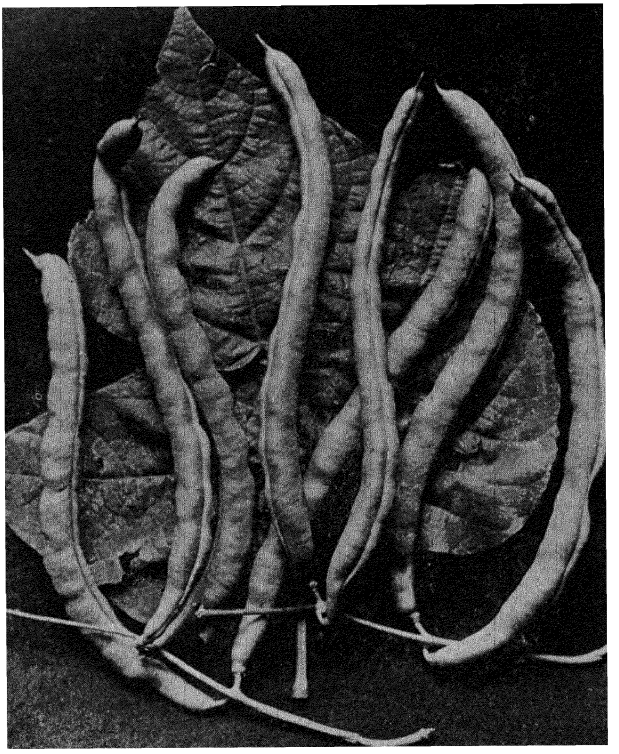


FIG. 151.—Kentucky Wonder beans, a variety of the common garden bean (*Phaseolus vulgaris*). (*Courtesy of the Massachusetts State College.*)

Cowpeas

The cowpea (*Vigna sinensis*) in spite of its name is more closely related to the beans than to the peas. It is a vigorous bushy or trailing summer annual, with curious, cylindrical, pendant pods. The plant grows indefinitely as long as the environmental conditions are favorable. The cowpea is a native of Southeastern Asia, where it has been grown for over 2000 years. It has been introduced into the tropics and subtropics of both hemispheres,

reaching the West Indies in the seventeenth century and the United States in the eighteenth. The seeds (Fig. 149, *G*) are fed to cattle and poultry, and are sometimes used as a coffee substitute. However, its chief value is as a forage crop, as a cover crop to prevent erosion, and as a green manure. The cowpea is an important crop in China, India, and the southern United States, where it is increasing in prominence. It is susceptible to frost and so is grown only in warm humid areas in a sandy or loamy soil.

Soybeans

The soybean (*Glycine Soja*) is a small, bushy, erect or prostrate annual (Fig. 92) resembling the cowpea. It is a much better crop, however, for it does not become tangled, matures earlier, has a larger yield, produces a better seed, and can be threshed. The seeds all mature at the same time and are shed when they are ripe. The soybean is a native of Southeastern Asia, where over 1000 varieties are grown, Manchuria leading in commercial production, followed by Korea, Japan, and the Dutch East Indies. It is easily the most important legume in the Far East, where soybeans are used everywhere in the daily diet of the natives to supplement rice. The seed is the richest natural vegetable food known. It also has manifold other uses, both in the Orient and in temperature regions. Soybean sauce, made from cooked beans, roasted wheat flour, salt, and a ferment, is widely used. The flour, with a low carbohydrate and high protein content, is an excellent food for diabetics. Soybean milk, extracted from the seed, is used in cooking and is recommended for infants and invalids. Soybean sprouts are a favorite food. Soybean oil, an important drying oil, has already been discussed. The soybean is rapidly assuming a position of great importance in the agriculture of the United States. The 1935 production of 43,631,000 bu., 50 per cent of which were grown in Illinois, is twice as large as the output for 1934. It can be grown under quite variable soil and moisture conditions, but requires a warm temperature and is susceptible to frost.

Broad Beans

The broad bean (*Vicia Faba*), also called the Windsor, horse, or Scotch bean, is grown as a forage crop, as well as for the seeds,

which furnish food for both man and the domestic animals. The plant is a strong erect annual, 2 to 4 ft. in height, with flat pods and large seeds (Fig. 149, *F.*). It has been cultivated since prehistoric times and probably originated in Algeria or Southwestern Asia. Over 100 varieties are grown, chiefly in the Old World. The broad bean was the only edible bean known in



FIG. 152.—A field of Virginia bunch peanuts (*Arachis hypogaea*). (*Reproduced from U.S.D.A. Farmers' Bulletin* 1656, *Peanut Growing.*)

Europe before the time of Columbus. It is still an important crop in England. Its growth is restricted by dry hot summers, so it is not grown to any great extent in North America, except in Canada. The broad bean is sometimes used as a cover crop, in crop rotation, and for fodder and silage, as well as for the seeds.

Peanuts

The peanut (*Arachis hypogaea*) is a true legume rather than a nut, for the shuck is merely a shell-like pod. The plant is a bushy or creeping annual with the peculiar habit of ripening its fruit underground. The peanut is a native of Brazil but was early carried to the Old World tropics by the Portuguese explorers. It was brought to Virginia from Africa by the slaves and is now

one of the most important crops of the South. In 1935, 1,702,435,000 lb. were grown, with Georgia the leading state. The commercial development has come about since the Civil War. As many as 20 kinds of peanuts are grown, differing in habit and the size of the pod. Peanuts require ample warm sunshine and a moderate rainfall. They can be grown successfully only south of 36°N.L. A sandy soil is best, although any but a low soil can be utilized. The soil must be friable so that the ripening fruit can be buried, and it must be well fertilized. In harvesting the crop (Fig. 152), the rows are plowed and the plants are lifted out with forks, shocked, and capped to cure. Later the fruits are removed, cleaned, and polished. The plants may be used for forage, stock feeding, or as soil renovators. The nuts or seeds are used for roasting or salting, in candy, and for the preparation of peanut butter. For the latter purpose the seed coats and embryo are removed and the nuts are roasted either dry or in oil, and are then ground to a paste. Peanuts are a very nutritious food. One lb. yields 2700 cal., whereas 1 lb. of beef furnishes only 900 cal. Peanut oil, an important food oil, has already been discussed.

Lentils

The lentil (*Lens esculenta*) is one of the most ancient of food plants and also one of the most nutritious. It is a native of Southwestern Asia, and was early introduced into Greece and Egypt. Lentils are frequently referred to in the Bible. The plant is a slender, tufted, much-branched annual with tendrils. The pods are short and broad, with small lens-shaped seeds (Fig. 149, *H*). The seeds are widely used, chiefly in soups. They are more digestible than meat and are used instead of meat in many Catholic countries during Lent. The plants are somewhat used for fodder.

Cajan Peas

The cajan pea or pigeon pea (*Cajanus Cajan*) is one of the most promising legumes at the present time. It was first domesticated in Asia or Africa and is now widely cultivated in the tropics, particularly in the East Indies, India, and the West Indies, where over 30 kinds are grown. The plant is an erect shrub. Both the immature and ripe seeds (Fig. 149, *D*) have

been used for human and animal food since earliest time. In recent years the plant has been developed as a forage crop and rivals alfalfa in importance. It is drought resistant, grows well in any soil, matures rapidly, and in many other ways is highly desirable. Livestock and poultry are particularly fond of it.

Lablab

The Lablab or bonavist bean (*Dolichos Lablab*) is an important legume in many tropical countries. The plant is a woody climber with a large yield of pods, continuing over several years. Both the pods and the seeds (Fig. 149, *B*) are eaten, and the plant is also used for hay and forage, chiefly for horses and cattle.

Horse Beans

The horse beans or Jack beans (*Canavalia ensiformis*), natives of the West Indies, are grown in nearly all tropical countries for their seeds. The plants are bushy annuals with long sword-shaped pods, containing 12 large beans. The unripe seeds and pods are used for human consumption, and the whole plant can be used for green forage. The plants are hardy, drought resistant, and immune to most pests. They are grown to a considerable extent in the southern United States.

Velvet Beans

The velvet bean (*Stizolobium Deeringianum*) is widely cultivated in the tropics for its edible seeds (Fig. 149, *A*) and for fodder. The plant, an annual herbaceous climber, exceeds all the other legumes in the rapidity and extent of growth. It is becoming of increasing importance in many of the southern states, particularly in Georgia and Alabama.

Kudzu Bean

The kudzu bean (*Pueraria Thunbergiana*), a native of Japan and Eastern Asia, has recently been introduced into the United States. It is a perennial vine that yields good hay and forage. The pods are also used, and a valuable starch is obtained from the large roots.

Forage Legumes

Many legumes are grown entirely as forage crops or for green manuring, and have no value as human food. New species are

being constantly introduced into the United States, so that the number of legumes actually cultivated increases every year. Among the most important of these are alfalfa (*Medicago sativa*), bur clover (*Medicago hispida*), bush clover (*Lespedeza striata*), medic (*Medicago lupulina*), sweet clover (*Melilotus alba*), the *vetches* (*Vicia sativa* and *V. villosa*), and the clovers. The latter include the alsike clover (*Trifolium hybridum*), crimson clover (*T. incarnatum*), red clover (*T. pratense*), and white clover (*T. repens*).

TREE LEGUMES

Although most of the leguminaceous food plants are herbaceous, there are a few trees that bear edible pods. These tree legumes and their importance to the future of agriculture have been brought to the attention of the public in recent years largely through the efforts of Professor J. Russell Smith. Erosion, one of the greatest enemies of agriculture, is greatly increased by excessive cultivation of the soil. This cultivation, however, is necessary in growing cereals and many other herbaceous plants. To remedy this condition, which, if unchecked, might lead to the destruction of all our arable lands, Professor Smith advocates the use of tree crops in place of cereal grasses. Many trees are already grown for their edible fruits and nuts, and many more could be domesticated and improved. There are, moreover, a few tree legumes that are excellent substitutes for wheat, corn, and other cereals in stock feeding. The most important of these are the algaroba, carob, and honey locust.

Algaroba

The algaroba, mesquite, or keawe (*Prosopis chilensis*) is a native of the arid regions of the West Indies, Mexico, and Central America. A single tree was introduced into Hawaii and from this small beginning the keawe spread until it now covers 50,000 acres and has become one of the most valuable trees on the island. The flowers are a source of honey, and the pods, and ground beans as well, are an important stock feed. The tree (Fig. 153) has an enormous yield, from 2 to 10 tons per acre, and over 500,000 bags are produced annually. It has been estimated that 1 acre of algaroba produces 1600 lb. of beef, while 1 acre of corn or alfalfa produces only 450 lb. The tree grows very rapidly, is drought

resistant, and can utilize arid, barren ground, where no other crop will grow. Algarobas are now being cultivated in many other parts of the world with a similar climate.

Carob

The carob bean (*Ceratonia Siliqua*) is a native of Syria, and has been cultivated from antiquity in the Mediterranean countries.



FIG. 153.—A large specimen of algaroba (*Prosopis chilensis*) near Honolulu, Hawaii. (*Photo by U.S. Forest Service*)

It constituted the "locusts" that were the food of John the Baptist and the Prodigal Son. The pods have been fed to farm animals for ages. More recently carob beans were almost the only food available for the cavalry horses in Wellington's peninsula campaign and Allenby's campaign in Palestine. The tree is a small evergreen with glossy green foliage. It blooms in the autumn and carries the young fruit until late the next summer. It prefers rocky dry soil. The carob is very productive with an exceedingly high yield. The dried pods (Fig. 154) contain 50 per cent sugar, and are often sold in the cities to be eaten like candy. The United States imported 1,234,316 lb. in 1935 for use in flavoring dog biscuit and chewing tobacco and for other purposes. The trees are now being grown with success in California. The

ground-up seeds yield a highly nutritious meal. Several bakeries are now making a bread which contains 25 per cent carob flour. The pods also contain a valuable gum known as tragasol.

Honey Locust

The honey locust (*Gleditsia triacanthos*) is a native tree of the humid eastern United States, a region with hot summers and cold winters. The pods contain 29 per cent sugar and are readily

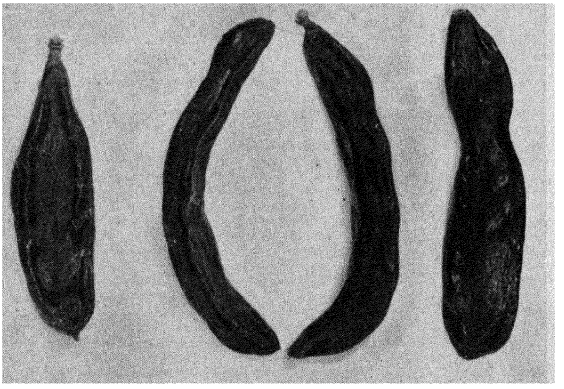


FIG. 154.—Dried carob beans, the pods of *Ceratonia Siliqua*, purchased in a Boston market.

eaten by animals. As it is also ornamental and a valuable timber tree, it should be given serious attention as a cultivated crop.

Other Tree Legumes

Other woody plants with edible pods occur in many parts of the world. Another mesquite (*Prosopis glandulosa*), a spiny shrub of the arid southwestern desert regions of North America, has pulpy pods that have long been used as food by man and beast. The rain tree (*Samanea Saman*), a huge tree of tropical America, bears curved black pods full of a sweet pulp, which is an excellent stock feed. The nittas (*Parkia biglobosa* and *P. filicoidea*) of West Africa have large pods with a 31 per cent sugar content. The seeds yield a very nutritious flour with 36 per cent protein, 23 per cent fat, 15 per cent starch, and 12½ per cent sugar. They are much used by the natives when traveling, as they constitute a concentrated natural ration. In Panama and Peru *Inga edulis*

and other species of the genus are cultivated for their edible pods, which have a sweet and agreeable pulp.

NUTS

Very few botanical terms are used more loosely than "nut." Technically a nut is a one-celled, one-seeded dry fruit with a hard pericarp (shell). A few of the so-called nuts of commerce answer this description. Among them are the acorn, chestnut, filbert, and hazelnut. The others may be seeds, as the Brazil nut; legumes, like the peanut; or dry drupes from which the outer parts of the fruit have been removed, such as the almond, coconut, pecan, and walnut. For convenience all these "nuts" will be considered together, regardless of their morphological nature.

Nuts are a valuable food material, and have been used as such for a long time, although in the United States they have been considered more as a confection until comparatively recently. Nuts are inexpensive, for they are produced in abundance and are easy to obtain. Because of their low water content they are a concentrated food, and also keep and handle well. They can withstand transportation, rough handling, and low temperature. If kept cool they rarely spoil; otherwise they may deteriorate by becoming wormy, rancid, or musty.

The food value of nuts is due chiefly to a high protein and fat content. However, they also contain starch, and sometimes sugar, and so furnish a well-balanced diet. For some reason, chiefly lack of knowledge, nuts have been considered indigestible. As a matter of fact, the reverse is true, and they are used as food by thousands of people, especially in the tropics where meat is scarce. Unless nuts, like any other food, are eaten in too large quantities, they are harmless. They may be eaten raw or cooked, or in the form of nut butters and pastes. They are often ground up to serve as coffee substitutes. Nuts are marketed in the shell or shelled. The former are often bleached, polished, or stained for the sake of appearance. The latter are apt to collect dirt in the crevices, and should be thoroughly cleaned before using.

Owing to the increasing value of nuts and the readiness with which nut-bearing trees can be grown on nonagricultural land, considerable attention is being directed to them with a view to improvement. Experiments are being carried on in selection and hybridization, which promise important results.

In general, three groups of nuts can be recognized: those with a high fat content, those with a high protein content, and those with a high carbohydrate content.

Nuts with a High Fat Content

Brazil Nut

The Brazil-nut tree (*Bertholletia excelsa*) is a rough-barked giant of the Amazon forests in South America. It bears from

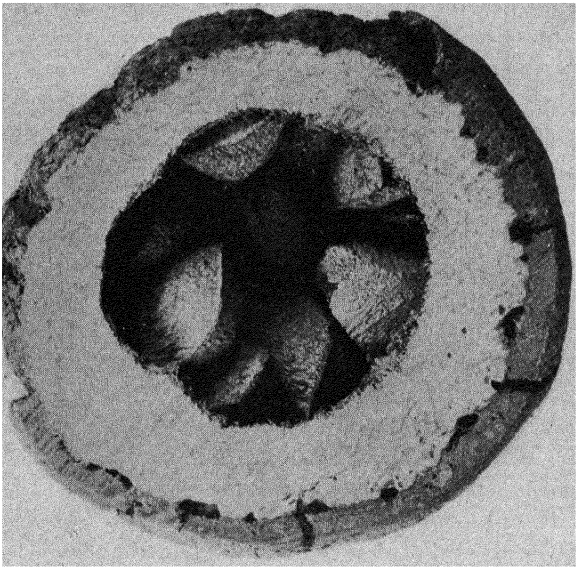


Fig. 155.—Section of the fruit of the Brazil-nut tree (*Bertholletia excelsa*), showing the seeds. These seeds constitute the "Brazil nuts" of commerce. (*Photo by S. J. Record.*)

18 to 24 hard, brown, spherical, woody fruits from 4 to 6 in. in diameter. Each fruit contains from 12 to 24 seeds (Fig. 155) with a hard bony covering. These are the Brazil nuts of commerce, also called cream nuts or niggertoes. They have long been used by the natives for food. The collecting and shipping of these nuts is an important industry in South America. The trees are never cultivated and the entire output, over 17,000 tons, is obtained from the wild trees. Most of the supply is shipped to Europe or the United States. Attempts have been made to cultivate the tree in the Southern states, but it is too sensitive to cold. Similar

nuts of finer quality and more delicate flavor are obtained from the paradise-nut tree (*Lecythis Zabucajo*).

Cashew Nut

The cashew nut is obtained from *Anacardium occidentale*, a native tree of tropical America, which is now extensively culti-

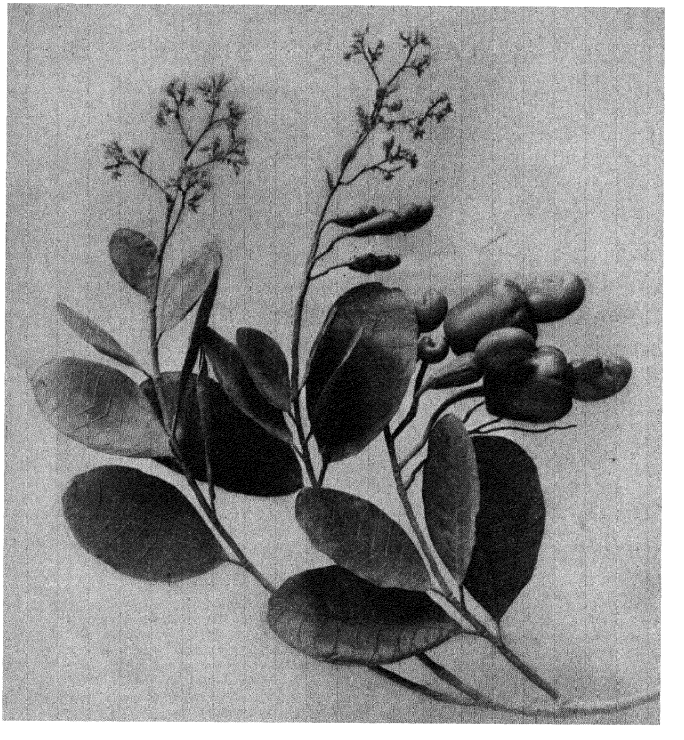


FIG. 156.—A glass model of the leaves, flowers and fruit of the cashew (*Anacardium occidentale*). (*Courtesy of the Botanical Museum of Harvard University.*)

vated from Mexico to Peru and Brazil, in the West Indies and southern Florida, in the Mediterranean area, in Mozambique, in India, and in the East Indies. The small unattractive evergreen tree bears a thin-skinned, pear-shaped, yellow or reddish, juicy "fruit" known as the cashew apple (Fig. 156). This is really the swollen peduncle and disk. The true fruit, a small curved or kidney-shaped structure, is borne on the outside of the "apple" at the distal end. This is the cashew "nut." The very rich

kernel is delicately flavored and these nuts have become justly popular in recent years. A nutritious oil can be extracted from the seed. The grayish-brown coat, or shell, contains an oil that blisters the skin. The ripe fruit, which has a characteristic aroma, is eaten in many countries or used for preserves; the fermented juice makes a wine, kajú, which is sometimes bottled. Between 2,500,000 and 3,000,000 lb. of cashew nuts are exported from

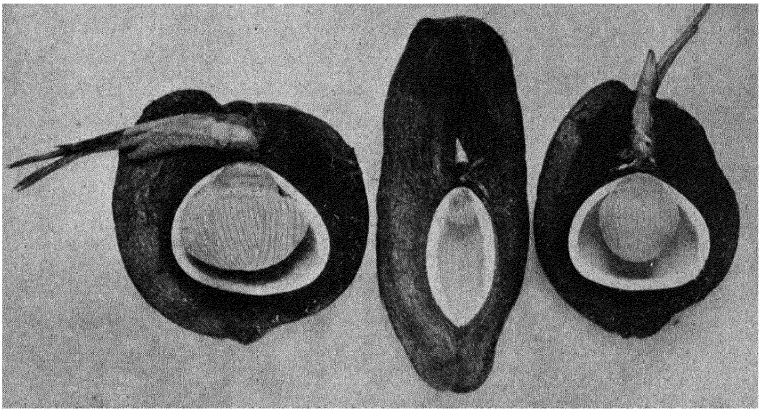


FIG. 157.—Sections of coconut fruits, showing stages in germination.

South America, and the vast stands in Brazil have scarcely been touched.

Coconut

The coconut palm (*Cocos nucifera*) is one of the world's most important economic plants and is indispensable in the daily life of millions of natives of the South Seas and other tropical countries. The tree is a native of the Malay archipelago, but it has been carried to tropical and subtropical regions in all parts of the world. It usually grows near the seashore, but may occur to an altitude of 2000 ft. It is one of the most graceful and beautiful of the palms, often with a characteristic leaning habit. The bases of the slender trunks are swollen. The large pinnate leaves, from 12 ft. long and 18 in. wide, are borne in a cluster at the tip of the stem. The flowers are produced in a large compound spadix, enclosed by a spathe (Fig. 104). The fruit is a three-sided dry drupe (Fig. 157). It consists of a smooth rind, or exocarp; a

reddish-brown fibrous mesocarp; and a hard stony endocarp, or shell, which encloses the seed. The so-called coconut meat and milk represent the endosperm of the seed; the embryo is embedded in the hard endosperm. Coconuts, as they reach the world's markets, consist of the endocarp and its contents.

Few plants have more varied uses. The fibrous husk yields coir, which has already been discussed. The hard shell, or endocarp, is used for fuel, vessels and other containers, and a fine grade of charcoal. The water makes an agreeable and refreshing drink. The meat may be eaten raw or may be shredded and dried to form desiccated coconut. It is often ground up and pressed through a cloth after water has been added. The resulting coconut milk is very palatable and a good substitute for cow's milk, as it contains several vitamins. The chief use of the meat, however, is for copra, the source of coconut oil and oil cake. The unopened inflorescences yield a sweet liquid, which is converted into palm sugar or fermented to make palm wine, arrack, or vinegar. The leaves are used for thatching, baskets, hats, mats, and curtains; the petioles and midribs are used for fence posts, canes, brooms, needles, and pins. The trunk furnishes a strong, durable wood for houses and bridges. Some of the porcupine wood of commerce, much used for cabinetwork, is obtained from the coconut. The bud or heart at the apex of the stem, is eaten in salads or is cooked. The bark contains a resin and the roots a drug.

The coconut is essentially a tropical plant and thrives best within the actual tropics. It will grow in any kind of soil, but naturally prefers a fertile area. Wild trees are still an important source of coconuts, but for commercial purposes plantations are usually established. Mature nuts are planted in a nursery and barely covered. They germinate in a few months and the seedlings are transplanted when about a year old. Coconut growth is improved by proper spacing, clean cultivation, and intercropping. Cover crops, fertilization, and irrigation also help to maintain the yield. Flowering and fruiting go on continually, and ripe nuts can be obtained during every month in the year (Fig. 158). They are usually picked every two months. The yield and size of the nuts vary with the spacing and the variety planted. It takes from 3500 to 7000 nuts to produce 1 ton of copra, which yields 1200 lb. of coconut oil and 800 lb. of oil cake. One thousand nuts will yield 165 lb. of coir fiber.

Coconuts are husked by driving them against a sharp spike fastened in a piece of wood and wrenching them apart. An experienced man can husk from 1200 to 2500 nuts a day. The nuts are broken into two halves with a blow of a heavy dull knife. The dried meat or copra the most important commercial product,



FIG. 158.—The crown of a coconut palm showing the clusters of fruit and the large pinnate leaves.

is prepared in several ways. About half the supply is dried by simple native methods, using the sun or drying on racks over fires made from coconut shells. After a few days the meat curls away from the shell and can readily be detached. Copra prepared in this manner is dark colored and has an oil content of around 50 per cent. Plantation copra is dried within 24 hours by utilizing the sun during the day and heat from fires in drying houses during the night. This copra is white and has a higher

oil content, from 60 to 65 per cent. The best grade of copra comes from southern India, followed by that from Ceylon, Java, Malacca, Manila, Borneo, and Singapore.

Desiccated coconut, which is used by confectionery and candy makers and in cooking, is prepared from the best grade of nuts. These are cured for several weeks and then are carefully cracked and the meat is removed while fresh. This is washed and cut into threads and dried in a vacuum for an hour at 160°F. Ceylon produces most of the desiccated coconut, shipping over 50,000,000 tons annually to the United States and Europe.

The preparation and use of coconut oil, oil cake, and palm sugar have already been discussed.

At the present time India leads in the production of coconuts, followed by the Philippine Islands, the Dutch East Indies, and Ceylon. Brazil and the West Indies have been slow in developing the coconut as a crop, but the production center may be moved to the Atlantic in order to lessen the distance required for transportation. The United States is the chief consumer, with Europe second.

Hazelnut

Hazelnuts are common in the cool temperate regions of both hemispheres. The native American species, *Corylus americana* and *C. cornuta*, produce small nutritious and palatable nuts of no commercial importance. A larger European species, *C. Avellana*, is the source of the familiar filbert. This plant is extensively cultivated in Southern Europe and is now being grown in Oregon.

Hickory Nuts

The hickories are native American trees common throughout the eastern deciduous forest region. They belong to the genus *Carya*. One group, the bitternut hickories, contain a large amount of tannin and are not good for food, although they are eaten by animals. The second group has sweetish edible nuts. The best of these is the shagbark hickory (*Carya ovata*). Good hickory nuts are among the finest of the wild nuts of the United States. The trees show great promise under selection and experimentation. They can be grafted and crossed, and many new varieties, adapted to a wide range of soil and climatic conditions,

have been produced. The nuts yield a good salad oil, and the wood is a valuable timber.

Pecan

The pecan (*Carya Pecan*) is a native of the southeastern United States and Mexico. Originally obtained from wild trees, pecans have so increased in popularity that the trees are now being extensively cultivated in the Southern states, particularly in Texas and Oklahoma. With the introduction of new varieties, the area of production has been extended northward into Virginia, Indiana, and the upper Mississippi valley. The pecan industry is a profitable one for the trees are easily grown and begin to bear in three or four years after setting out, and the nuts command a high price. Factories are often located near the supply, and here the nuts are cracked and the meats picked out and prepared for shipment. Paper-shelled varieties, with a thin shell that can be broken with the fingers, have been developed recently. Pecans have a higher fat content than any other vegetable product, over 70 per cent

Pili Nut

Pili nuts, often found in mixed nuts, are the seeds of *Canarium ovatum*, a native tree of Eastern Asia, the East Indies, and the Philippine Islands, which has recently been introduced into the United States. These nuts, sometimes called Javanese almonds, are highly appreciated in the Orient, where they are eaten raw or roasted. They are spindle shaped and triangular in cross section with a very thick hard shell. In the tropics a fatty oil is expressed and used for eating and in lamps. The plumlike fruit of the pili is also edible. The tree yields a resin.

Pine Nuts

The pine nuts or piñons (Fig. 159) are the edible seeds of several species of *Pinus* that are native to the Rocky Mountain and Pacific Coast region. Among these are the nut pines, *P. edulis* and *P. monophylla;* the Digger pine, *P. Sabiniana;* and the Torrey pine, *P. Torreyana.* These nuts, which are about the size of a bean, with a thin brownish-red shell, are very popular. Over 1,000,000 lb. are consumed annually. The American Indians

have always eaten piñons. They roast the cones so that the scales will fall apart and allow the seeds to separate.

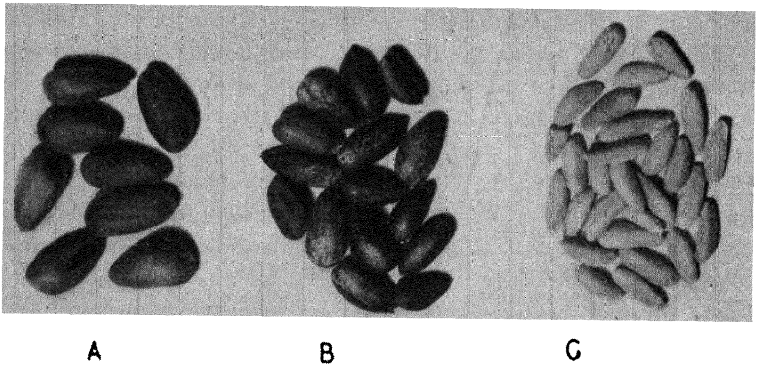


FIG. 159.—Pine nuts, the seeds of various species of *Pinus*. *A*, Torrey pine (*P. Torreyana*); *B*, piñon (*P. edulis*), *C*, stone pine (*P. Pinea*), a European species. These last seeds constitute the pignolia nuts of commerce.

The pignolia nut (Fig. 159, *C*) is the seed of *Pinus Pinea*, a species of Southern Europe. It is longer and yellower than our native pine nuts and has a rich delicious flavor. Large quantities are imported. Edible pine nuts also occur in India.

Walnuts

Walnuts are important for both their nuts and their timber. They are found in the eastern United States and in Europe as native trees.

The **black walnut** (*Juglans nigra*) is one of the chief trees of the eastern deciduous forest region of the United States. It is a tall handsome tree (Fig. 50) often cultivated for ornamental purposes. The large spherical fruits are green when ripe, and the outer covering has to disintegrate or be beaten off to free the nuts. The walnut kernels are rich in oil and were a favorite food of the Indians. They retain their flavor when cooked and have a food value four times greater than meat. Nevertheless they are not much used as table nuts. The chief market is in the candy and ice-cream industry. The tree is very productive and can be grown anywhere, attaining its best growth in rich alluvial soil. Walnuts furnish valuable timber, and also a brownish-black dye.

The **butternut** (*Juglans cinerea*) occurs as a native tree in the limestone areas of the eastern United States and adjacent Canada. It is a smaller tree with elliptical nuts, which have a deeply corrugated shell. Butternuts are rich in fats and are thought by many to have a finer and richer flavor than walnuts, although they have an oily taste. The kernels are obtained more readily. Butternuts are much used in the candy industry.

The **English walnut** (*Juglans regia*) in spite of its name is a native of Persia. It is extensively cultivated in Southern Europe, China, and other parts of Asia, and is now being grown in California and Oregon with great success. The English walnut has been cultivated for a long time, and many varieties are known. The beautiful trees are usually planted in rows. Only the outer limbs produce perfect nuts. The kernels are easily freed from the pericarps and are often bleached and polished. The characteristic furrowed kernels are the cotyledons of the seed, no endosperm being present. Walnuts yield an excellent oil for table use, and the oil cake is a good stock feed.

Nuts with a High Protein Content

Almonds

Almonds are obtained from a small tree (*Prunus Amygdalus*), which is related to the peach and closely resembles it in blossom and young fruit. The almond fruit is an inedible drupe, with a tough fibrous rind surrounding the stone (shell) and seed (nut). Two types of almonds occur.

The **sweet almonds** (var. *dulcis*) have an edible seed and are the source of the commercial product. The almond is a native of the eastern Mediterranean region and is grown throughout Southern Europe and also in California. The seeds are particularly delicious when eaten green. Usually, however, they are roasted or salted or made into a paste to be used in making bread or cake. Almond extract is also prepared. There are several varieties, some with paper shells and some with hard shells. Jordan almonds are a hard-shelled type with a thinner integument on the seed and a finer flavor. They are imported from Malaya, and are much used for confections. Imported almonds are marketed shelled, while American-grown ones are always in the shells.

The **bitter almonds** (var. *amara*) contain a bitter glucoside, which readily breaks down into prussic acid and so prevents their use as food. However, they are much grown in Southern Europe as a source of the oil of bitter almond. During the extraction process the prussic acid is eliminated, and the oil can be used for flavoring. Bitter almonds are also used as a stock upon which to graft sweet almonds.

Beechnuts

Beechnuts are the seeds of the beech tree (*Fagus grandifolia*), one of the most characteristic trees of the eastern deciduous forest region of North America. The nuts are small, triangular, and very sweet. They are of little importance for human food, but are eagerly eaten by pigs, squirrels, and birds. They give a fine flavor to pork, and razorback hogs are fed on mast, which is a mixture of beechnuts, chestnuts, and acorns. The European beech (*F. sylvatica*) yields slightly larger nuts, which are eaten and used for the edible oil of beechnuts.

Pistachio nuts

The pistachio or green almond (*Pistacia vera*) is a small tree native to Syria, but cultivated throughout Southern Europe, the southern United States, and California. The fruit is a drupe. The seeds contain two large green cotyledons with a reddish covering. These "nuts" are salted in brine while still in the shell. They are highly prized for their color and resinous flavor, and are much used in mixed nuts and as a flavoring material in ice cream and candy.

Nuts with a High Carbohydrate Content

Acorns

Acorns are the characteristic fruits of oaks (*Quercus* sp.). They are true nuts. In this country acorns have been used for ages as a fattening food for animals, particularly hogs. They are equally good for man and should be used more. The North American Indians have always used acorn flour. They ground up the nuts, leached them to remove the tannin and other bitter principles, pounded them into a meal, and used them in porridge, mush, and other ways. Acorns furnish 25 per cent of the food

of the poorer classes in Italy and Spain in the form of acorn bread or cake. This is highly nutritious and cheap and keeps indefinitely. Any species of acorn is edible after the tannin has been removed. Oaks are very productive, are precocious and rapid growers, and are well adapted to poor soil. They should



FIG. 160.—A fruiting branch of the chestnut (*Castanea dentata*), showing the nuts surrounded by the burlike involucre. (*Courtesy of the Arnold Arboretum.*)

be cultivated as commonly in this country as they are in the Mediterranean region.

Chestnuts

Chestnuts occur in the eastern United States, Japan, and Europe. The American species (*Castanea dentata*) was formerly very abundant in the deciduous forest region. It was a handsome tree and furnished valuable timber, as well as the familiar

nuts (Fig. 160), which had served as food, either raw or roasted, for over 200 years. The ravages of the chestnut blight disease have almost wiped out this tree in the last 20 years. The European chestnut (*C. sativa*) with larger fruits is extensively cultivated in Southern Europe. The nuts, or marrons as they are called, are a standard article of food, and are as important as corn is with us. They are grown everywhere on dry hillsides that are unfit for other purposes. The nuts are eaten raw or are roasted, boiled, or used for stuffing or flour. The Japanese chestnut (*C. crenata*) is immune to the chestnut blight and is being introduced into this country. Its nuts are edible, and are often cooked like potatoes.

1935 IMPORTS OF IMPORTANT NUTS

	Pounds		Pounds
Almonds, shelled	7,340,250	Filberts, unshelled	3,533,300
Almonds, unshelled	2,730,841	Peanuts, shelled	31,460
Almonds, blanched	816,512	Peanuts, unshelled	233,239
Brazil nuts, shelled	8,869,099	Pecans, shelled	265,635
Brazil nuts, unshelled	22,415,802	Pignolias, shelled	354,035
Cashews	22,376,432	Pistachios, shelled	376,197
Chestnuts	16,681,390	Pistachios, unshelled	2,714,882
Coconuts (nuts).	56,362,623	Walnuts, shelled	5,258,332
Coconut meat.	75,674,236	Walnuts, unshelled	308,277
Filberts, shelled . . .	2,104,314		

CHAPTER XVII

VEGETABLES

In a technical sense all plants are vegetables. The term, however, is usually applied to edible plants which store up reserve food in roots, stems, leaves, and fruits and which are eaten cooked, or raw as salad plants. Vegetables constitute a large and varied group of considerable importance in the world's commerce. Most of them are very old, and their origin as food plants is lost in antiquity. The food value of vegetables is comparatively low, owing to the large amount of water present (70 to 95 per cent). Even so, they rank next to cereals as sources of carbohydrate food. This is usually present in the form of starch, although occasionally sugar, pectins, or other substances may occur. Proteins, save in legumes, are rarely available, and fats are stored only in very slight amounts. The nutritive value of vegetables is increased greatly, however, by the presence of the indispensable mineral salts and vitamins, while the roughage value of the various tissues aids digestion. For convenience the vegetables may be classified as earth vegetables, herbage vegetables, and fruit vegetables.

EARTH VEGETABLES

The earth vegetables include all forms in which food is stored in underground parts. The storage organs may be quite different morphologically. Some are true roots, while others represent modified stems, such as rootstalks, tubers, corms, and bulbs. All these structures are especially well adapted to storage because of their protected position. Many wild, as well as cultivated, species have fleshy underground parts, and these have played a role in the development of civilization and agriculture second only to the cereals and legumes. From earliest time roots and tubers have furnished food for man and beast. Even though the amount of stored material is less than that in dry fruits and seeds, these are extremely valuable since they are readily digested and have a high energy content. One objection

to them is the high water content, which not oniy reduces the amount of available food material but impairs their keeping qualities as well. Their bulk, too, makes it impossible to transport and store them as efficiently as cereals, legumes, or nuts. Root crops, as these earth vegetables are often called, are an important phase of agriculture all over the world. In most countries they are grown fully as much for stock feed as for human consumption. In the United States root crops have been neglected more than they should have been, because it has been easier and cheaper to grow cereals which do not require so much hand labor. The various earth vegetables will be grouped according to their morphological origin. Of the many hundreds that are used for food throughout the world, only the most important can be considered.

Roots

Beets

The various beets now in cultivation—chard, mangels, sugar beets, and common beets—are all referred to a single species, *Beta vulgaris*. This has without doubt been derived from the wild beet (*B. maritima*) of the seacoasts of the Mediterranean regions and adjacent Europe. The beets are biennials, producing the first year a large cluster of leaves from a crown at the tip of a fleshy taproot.

Chard (var. *Cicla*) is the oldest type of beet. It was known as early as 300 B.C. For several centuries the roots were used, both as a vegetable and in medicine. Later the tender leaves were utilized. Under cultivation the leaves have been developed at the expense of the roots, and now chard has large leaves with thick stalks and roots that are very little enlarged. Chard is used almost entirely as a pot herb.

Mangels or mangel-wurzels have been developed from chard. They have the roots and the lower part of the stem thickened, with a crimson, golden, or white sap. Mangels have been an important cattle feed since the sixteenth century. They are extensively grown in Europe and in Canada. Although early introduced into the United States, they have never been of much importance. Mangels contain 3 to 8 per cent sugar. They are fed to cattle dry or are used for silage.

Sugar beets have been developed from the mangels. They are smaller and have a higher sugar content. Their cultivation and utilization as a source of sugar have already been discussed.

Common beets have been known since the beginning of the Christian era. Many varieties are grown, differing in size, shape, color, sugar content, and time of maturing. The early red beets are most desirable. Beets are boiled, pickled, or canned, and are often used for salads. The leaves and young beets, the familiar beet greens, are a favorite pot herb.

Carrots

The carrot (*Daucus Carota*) has been cultivated for over 2000 years. It was known to the Greeks and Romans, and reached Europe early in the Christian era. It was a favorite vegetable in England in the time of Queen Elizabeth, and was brought to Virginia in 1609 and New England in 1629. The Indians carried it over the rest of America. Carrots now are found all over the world, often as weeds with long dry taproots that have lost their fleshiness. They are usually biennials, but may mature in one year. The pinnately compound leaves are very characteristic. The numerous varieties of carrots differ in size, shape, color, and quality, and are correlated with differences in the soil. A deep sandy loam gives the best results. The roots are harvested just before the ground freezes and are stored in cellars. Most of the food is stored in the outer cortical portions of the taproot. The central portion remains somewhat woody and unpalatable. Carrots are eaten raw or cooked and are often used for flavoring soups and stews. They are a valuable food for animals, particularly horses. The yellow coloring matter, carotin, is sometimes extracted and used for coloring butter.

Oyster Plant

The oyster plant or salsify (*Tragopogon porrifolius*) is a hardy biennial with a large fleshy taproot, sometimes as much as 1 ft. in length. It is a composite, and when mature has large purple heads, with fruits resembling those of a dandelion. The plant is a native of Southern Europe, but is cultivated in many parts of the world, and often becomes established as a weed. The roots are cooked or are used as a relish. They have a flavor suggestive of oysters, which gives the name to the plant.

Parsnips

The parsnip (*Pastinaca sativa*) was used by the Greeks and Romans and has been cultivated in Europe ever since. It is figured in nearly all the old herbals. A native of Europe, it reached the West Indies in 1564, Virginia in 1609, and by the beginning of the eighteenth century was grown by all the American Indians. The plant tends to escape from cultivation and revert to its ancestral habit with tough dry roots. Seedlings from the wild forms, when brought into a more favorable environment, gradually resume the cultivated form. Parsnips are difficult to harvest for the roots are entirely below ground. They have a considerable sugar content and even some fat. They are used as food by man and livestock, and also for making wine.

Radishes

Radishes (*Raphanus sativus*) are annual or biennial plants with a fleshy taproot and rosette of small leaves, which later are replaced by the erect flowering and fruiting part of the plant. They have been cultivated for over 2000 years, but are still close to the ancestral type and often revert to a form with a dry woody root. Radishes are grown all over the world, and are highly esteemed because of their pungent flavor. Many varieties are in cultivation differing greatly in size, shape, and color of the roots. Early, summer, and winter types occur, and they are often forced in hot beds. Radishes are usually eaten raw, but may be cooked like any other vegetable.

Turnips and Rutabaga

The turnip and the rutabaga are very closely related, and are sometimes considered as varieties of a single species, *Brassica campestris.*

In the **turnips** (*Brassica Rapa*) both the root and the lower part of the stem are fleshy and rough. The flesh varies in texture. Those with a fine texture are used by man, while the coarser forms are fed to stock. Turnips have been grown for nearly 4000 years, and have spread from the original home in temperate Europe all over the world. They reached Mexico in 1586, Virginia in 1610, and New England in 1628. Many types are grown differing chiefly in the shape and color of the

root. Turnips thrive best in cool climates. They are used more in Europe than in the United States. Turnip tops are used for greens and for forage and manuring.

The **rutabagas,** or swedes (*Brassica Napobrassica*), have a larger smooth root, with a short neck composed of stem tissue. Their flesh is more solid, and so they keep better. They grow best in northern regions where the cool climate favors the development of the characteristic sweet flavor. Rutabagas are fed to stock and are also eaten by man in large quantities.

Sweet Potatoes

The sweet potato (*Ipomoea Batatas*) is a native of tropical America, where it was probably first grown by the Incas as early as 3000 B.C. By the beginning of recorded time it was cultivated in the tropics of both hemispheres. Although today it is widespread in all tropics, and is particularly abundant in the South Seas, it is definitely of American origin. The sweet potato, together with the cassava, yam, and taro, are practically indispensable to the tropical natives. These humble root crops are cheap, are available throughout the year, and grow in every soil. Although of little commercial importance and rarely marketed, they are found in every native garden patch.

The sweet potato is a twining, trailing perennial vine with adventitious roots that end in swollen tubers. These contain both starch and sugar, and even a little fat. The sweet potato requires a sandy soil and a warm moist climate. In the United States the Atlantic coastal plain, from the Gulf States as far north as New Jersey, is the chief producing area. The plants are propagated vegetatively by using the roots, or pieces of roots, or vine cuttings. The yield is low, and attempts should be made to improve it. This is particularly true in the poorer tropics where the sweet potato is such an essential plant. Two types are grown (Fig. 161). The first type has a dry, mealy yellow flesh and is much preferred in the North. The second type, often erroneously called yams, has a more watery, soft, gelatinous flesh, which is richer in sugar. This is the favorite type in the South, where sweet potatoes are a staple crop and next to white potatoes in importance. Sweet potatoes are not only a common table vegetable, but they are used for canning, dehydrating, flour manufacture, and as a source of starch, glucose syrup, and

alcohol. They are fed to horses, cattle, and hogs. The green tops are used for fodder. Because of their high water content, sweet potatoes spoil readily and about a third of the crop is usually lost.

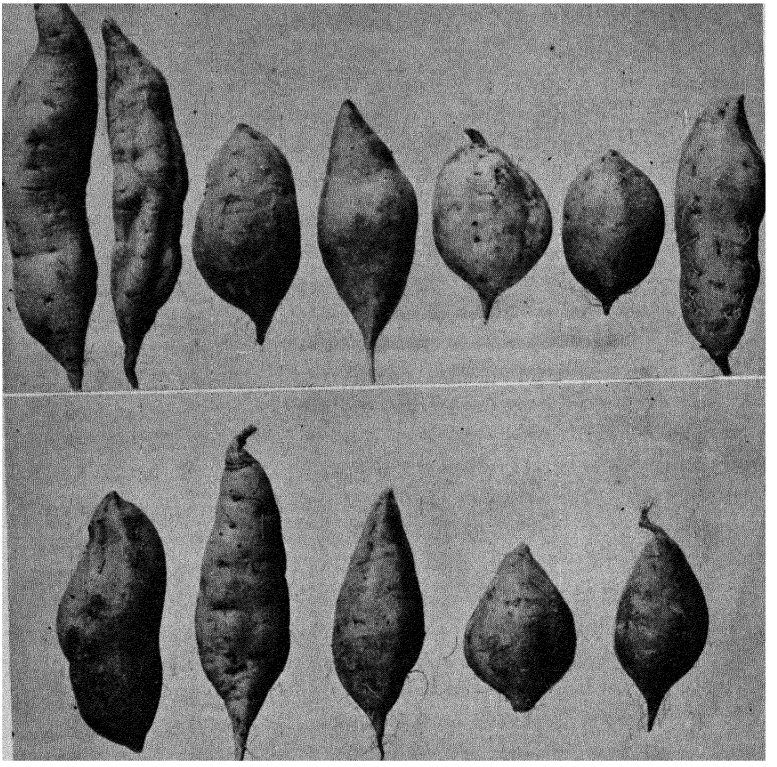


FIG. 161.—Varieties of sweet potatoes (*Ipomoea Batatas*). Above, sweet moist-fleshed varieties; below, dry, mealy-fleshed varieties. (*Reproduced by permission from Etheridge, Field Crops, Ginn and Company.*)

Yams

The true yams belong to the genus *Dioscorea*. There are a great many species in the tropics and subtropics of all countries, and they are difficult to distinguish. The most commonly cultivated species is *D. alata*. The yams are all climbing vines with large storage roots, often weighing as much as 30 or 40 lb., and sometimes with aerial tubers as well. They require a deep

soil, but are quite drought resistant. Yams are the chief food of millions of people in the West Indies, South America, the South Seas, and the Asiatic tropics. They are baked or boiled or ground into flour. Yams are becoming a crop of increasing importance in the southern United States, where they are used to feed hogs and other livestock.

Cassava

Next to the sweet potato, the cassava (*Manihot esculenta*), is the most important of the tropical root crops. It is a native of



FIG. 162.—Mature cassava plants (*Manihot esculenta*). (*Courtesy of the Minute Tapioca Company, Division of General Foods Corporation.*)

South America, but is widely grown in all tropical and subtropical regions. Over 150 varieties are known, most of which are used by the native peoples for food. Two main groups are usually recognized—the bitter cassavas and the sweet cassavas. The cassavas (Fig. 162) are shrubby perennials with stems that reach a height of 9 ft., deeply 3- to 7-parted leaves, and roots that end in very large tubers. All the varieties contain a little prussic acid, and some are quite poisonous. In most cases, however, a slight amount of heat is sufficient to drive off the volatile acid and render the material harmless. Cassava, or manioc as it is

often called, is one of the most wholesome foods. It is eaten by all classes of people in South and Central America at least twice a day throughout the year, and it has been estimated that over 7000 tons are produced in these countries annually. The crop is easily grown with but little labor. It is propagated by stem cuttings, using pieces 6 to 10 in. long. The plant matures in from seven months to a year. The yield is large, 1 acre producing upward of 6½ tons. The roots of a single plant may weigh from 25 to 50 lb.

The tubers are eaten raw or are cooked. A meal is prepared by peeling, washing, and scraping or grating the tubers, and then placing the material in a bag where the liquids are squeezed out. After drying and sifting, the meal is baked into thin cakes, known as cassava bread. This has a high food value and replaces wheat bread in the diet. The poisonous milky juice is concentrated to a thick consistency by boiling, and constitutes cassareep, or West Indian pepper pot, which is used as the basis of many sauces. Raw cassava starch is used for healing purposes, and is fermented into an intoxicating beverage. It is also fed to live-stock and used for laundry work and sizing.

Much of the raw cassava is used in making tapioca. For this purpose the roots are peeled and grated and the milky juices are expressed. The starchy material is then soaked in water for a few days, is kneaded, and is strained to remove any fibers and impurities. After sifting and drying in the sun, it is heated gently on hot iron plates. This partially cooks the starch and causes it to ball up into the familiar little round lumps, which constitute the tapioca of commerce. The United States imports tapioca chiefly from Brazil and the East Indies.

Underground Stems

Jerusalem Artichoke

The Jerusalem artichoke (*Helianthus tuberosus*) is a native plant of North America and has been cultivated by the Indians for centuries. It is a hardy perennial sunflower 6 to 12 ft. in height. The name is derived from the Italian word for sunflower, *girasole*. The plant was introduced into Europe in 1616, and has always been cultivated more extensively there than in this country; many new and improved varieties have been developed.

The Jerusalem artichoke is adapted to almost any climate but does best in the Northern states and Canada. The tubers, which somewhat resemble potatoes, but with larger eyes, are cooked, pickled, or eaten raw. The carbohydrate food is in the form of inulin, which is a good food for diabetics, and is also used as a source of levulose and industrial alcohol. The plants are also grown as a forage crop and weed eradicator.

Potato

The white or Irish potato (*Solanum tuberosum*) is one of the most important food plants of the world. It is a native American



FIG. 163.—Tubers of the white potato (*Solanum tuberosum*). (*Courtesy of Breck and Company.*)

species and was cultivated from Chili to New Granada at the time the Spanish explorers reached this continent. The first mention of the potato in literature was in 1553 in Pedro de Leon's "Chronica del Peru," while the first published illustration appeared in Gerard's Herbal in 1633. The potato was introduced into Europe soon after 1580 by the Spaniards, and by the end of the seventeenth century it had spread all over Europe and the British Isles. The potato was first introduced into New England by Irish immigrants in 1719. Possibly it had been carried to Virginia and the Carolinas at an earlier date, but it did not spread farther.

The potato is an erect, branching, more or less spreading annual from 2 to 3 ft. in height. It has pinnately compound leaves,

fine fibrous roots, and numerous rhizomes which are swollen at the tip to form the familiar tubers (Fig. 163). The flowers are white, yellow, or purple, with a tubular corolla, while the fruit is a small brownish-green or purple inedible berry.

Potatoes are adapted to many soils and many climates. They are, in fact, grown the world over, except in low tropical regions. They are hardy and mature rapidly, and so can be grown as far north as 60°N.L. and at altitudes up to 8000 ft. The best environment is a cool moist climate, with a mean annual temperature of 40 to 50°F., and a rich light soil.

Potatoes are usually propagated vegetatively by means of tubers, or parts of tubers, the so-called "seed potatoes." They may, however, be grown from seed. The famous Burbank potato was obtained in 1871 from seed. The 500 or more varieties now in cultivation have been obtained by selection and hybridization and by the utilization of mutations, which are of frequent occurrence. The essential parts of the seed potatoes used for propagation are the eyes. These are really groups of buds situated in the axils of aborted leaves. There is usually a central bud in each eye, surrounded by smaller lateral ones. The eyes are more numerous toward the apex of the tuber. Pieces of the tubers are cut at right angles to the main axis so as to remove the inhibiting effect of the terminal bud. The larger the piece, the more vigorous is the vegetative growth, and there is a correspondingly greater yield. In any case, at least one eye must be present. The tubers have a rest period of several weeks' duration after they have matured, during which they will not sprout. This is a period of afterripening in which various physiological changes take place. The duration of the rest period can be controlled by the use of cold and by various gases and chemicals.

Within the tubers several regions can be noted. These include the skin or periderm varying in color, texture, and thickness; the narrow cortex, a dense area with small starch cells; a ring of fibrovascular bundles; the external medulla, which contains most of the starch; and the internal medulla, which has a much greater percentage of water and less starch. Branches of the internal medulla extend outward toward each eye. In all these areas the starch occurs in characteristic oval grains of varying sizes in thin-walled parenchyma cells. The mealiness

of the potato is due to the swelling of the grains and the rupturing of the cell walls. If the external layers are poor in starch, the walls do not burst and the tuber is soggy. Potatoes contain about 78 per cent water, 18 per cent carbohydrates, including a little sugar as well as starch, 2 per cent proteins, 0.1 per cent fat, and 1 per cent potash. They are well adapted to storage if a cool dark place is provided. The water loss over winter amounts to about 11 per cent.

Over 90 per cent of the potato crop of the world is grown in Europe, where it exceeds the wheat crop of the world in volume

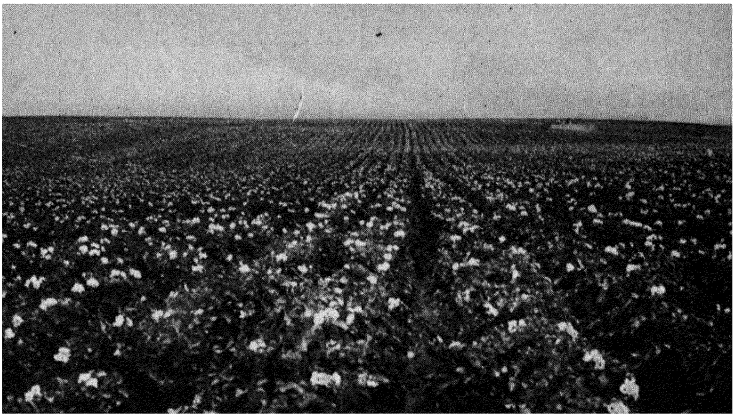


FIG. 164.—A field of potatoes in blossom in Aroostook County, Maine. (*Courtesy of the Maine Agricultural Experiment Station.*)

and value. Of the 1934–1935 world production of 6,183,000,000 bu., Germany produced 1,718,876,000 bu., Russia 1,600,000,000 bu., Poland 1,230,000,000 bu., France 612,000,000 bu., and Great Britain 201,000,000 bu., while the United States produced 385,421,000 bu. Potatoes are grown more universally than any other crop, and are cultivated in all but seven counties of the United States. They are grown in the Northern states in the summer and in the Southern states in the late winter and early spring. They are a valuable small farm and garden crop for they will grow in any soil and have a high yield. The commercial production of potatoes is often concentrated in areas where both the climate and market conditions are most favorable. Chief among these are the Aroostook region in Maine (Fig. 164),

Long Island, N. Y., southern New Jersey, Pennsylvania, and the eastern shore of Maryland. Maine leads in production. Other important states are Minnesota, New York, Michigan, Wisconsin, Pennsylvania, and Idaho.

In the United States potatoes are used chiefly for human consumption and are a universal table food. Small tubers are utilized for the production of starch and industrial alcohol, and they are also fed to stock. In Europe a considerable part of the crop is used for industrial alcohol.

Taros and Dasheens

The taros and dasheens are next to yams in importance in the Orient. They are among the few edible aroids and belong to the genus *Colocasia*. Over 300 varieties occur in Polynesia, Malaya, and Southeastern Asia, where the plants are native, and they constitute the staple food of millions of people. There is no erect stem, but a cluster of large leaves from 4 to 6 ft. in length.

The **taro** (*C. esculenta* var. *antiquorum*) has huge peltate leaves. It has been cultivated for so long that it never flowers. Probably no civilized man has ever seen a taro seed. The top of the corms are used for propagation. Taros require a wet rich soil and a long season in which to mature. The yield is high and the starch is exceedingly wholesome and readily digested. It is an interesting side light that there is no word for indigestion in the Kanaka language. The taros are baked or boiled to destroy the acrid principles in the raw tubers. One of the principal dishes of the Polynesians is *poi*, a thin pasty mass of taro starch. This has a faintly acid taste and is very palatable. It is often made into cakes and baked or toasted.

The **dasheen** (*C. esculenta*) has large tubers, with smaller ones on the side (Fig. 165). The flesh is mealy with a nutty flavor, and has more carbohydrates and proteins than the potato. Since 1913 dasheens have been grown as a commercial crop in the southern United States, and the tubers are increasing in popularity as a potato substitute.

Yautias

The yautias are among the least known but are probably the oldest of the root crops. These plants are found only in tropical

America. The commonest species is *Xanthosma sagittifolium.* The yautias resemble the taros, to which they are closely related. They are taller, reaching a height of 7 or 8 ft., with arrow-shaped leaves, and produce both corms and tubers. These plants are common in the West Indies, especially in Puerto Rico, and many

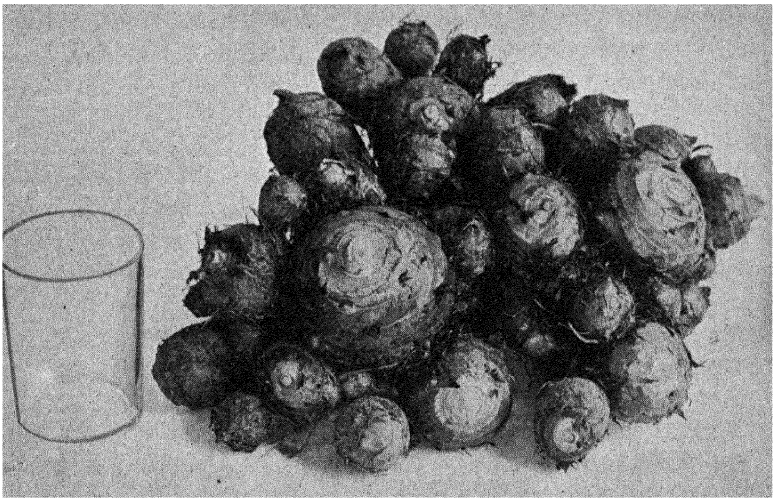


FIG 165.—Tubers of the dasheen (*Colocasia esculenta*). (*Reproduced from U.S.D.A , The Dasheen as a Root Crop for the South*, 1913)

varieties are grown. The tubers are twice as nutritious as the potato.

Onions

The onion (*Allium Cepa*) is the chief food plant in which the food is stored in a bulb. It is very old, its use going back over 4000 years beyond the beginnings of authentic history. It is unknown in the wild state. The onion was probably a native of Southern Asia or the Mediterranean region. It has long been valued in China and India for its flavoring. In Egypt it was worshiped before the Christian era, and it also played a part in the Druid rites. Onions are cultivated over large areas in temperate and even tropical climates. They prefer cool moist regions with a sandy soil. They are grown from seeds or sets, small bulblets that are produced instead of flowers. Onions have to be dried (Fig. 166) and cured before they are stored in

order to develop the characteristic flavor and taste, which are due to an acrid volatile oil, allyl sulphide. They are both food plants and flavoring agents. Over 250 species of *Allium* are known, some of them native to boreal America. Many occur as weeds. The commonest forms in cultivation are garlic, leeks, chives, shallots, and the true onions.

The **garlic** (*Allium sativum*) is a perennial plant with narrow flat leaves and several small egg-shaped bulbs, known as cloves,



FIG. 166.—Onions (*Allium Cepa*) drying in windrows. (*Courtesy of the Massachusetts State College.*)

enclosed in a white skin. The inflorescences produce both seeds and bulblets. The latter, together with the cloves and the leaves, have been used from earliest time for flavoring soups, sausages, and salads. Garlic also has a medicinal value as it possesses antiseptic and bactericidal properties.

The **leek** (*Allium Porrum*) is a very old plant. It is a robust perennial of the Mediterranean region with rather thick, flat, broad leaves and small bulbs. The bases of the leaves are mild flavored and edible and they are often blanched like asparagus. Leeks are also used in seasoning.

Chives (*Allium Schoenoprasum*) have hollow and cylindrical leaves with very small clustered bulbs and dense umbels of

rose-colored flowers. They are hardy perennials growing in dense clumps. The young leaves and bulbs are used for seasoning.

Shallots (*Allium ascalonicum*) likewise have cylindrical hollow leaves, but the plants are not cespitose. They are perennials with large clustered bulbs, which are much used for pickling. The leaves are short and awl shaped.

The **true onions** (*Allium Cepa*) are biennials with a single large bulb and long, hollow, cylindrical leaves. From each bulb arises a single leafless scape as much as 2 or 3 ft. in height, with numerous small flowers. There are many different forms with either round, flat, white or colored bulbs. The foreign onions, like the Spanish and Bermuda onions, are larger, less hardy, and milder than the domestic types. Onions were brought to America by the early colonists. They are propagated by division, bulblets, and seeds. They are used for flavoring, as a vegetable, for pickles, and in medicine. They are easily digested and are good for constipation. An extract of onion is available for flavoring purposes.

HERBAGE VEGETABLES

Herbage vegetables have the nutrient materials stored in parts of the plant developed above ground. They are the familiar pot herbs and salad plants. Almost any part of the shoot system of the plant may be utilized for storage. The leaves are used in kale, cabbage, spinach, and lettuce; stems in asparagus and kohlrabi; buds in Brussels sprouts; leafstalks in celery and rhubarb; and immature flowers and flower stalks in cauliflower and broccoli. The chemical composition and food value of herbage vegetables are close to those of the earth vegetables. There is more water, however, and a correspondingly smaller amount of carbohydrates. They contain more proteins, since the leaves are the workshop of the plant, and also a considerable amount of mineral salts and vitamins, which makes them an essential part of man's diet. There is also some roughage value.

Artichoke

The globe artichoke (*Cynara Scolymus*) is a native of the Mediterranean region and the Canary Islands. The plant resembles a thistle in size and habit. The flower stalks terminate

in globular inflorescences with numerous subtending involucral bracts (Fig. 167). The immature heads together with the fleshy bases of the involucral leaves and the thickened receptacle are eaten either raw or cooked. Artichokes grow best in low ground near the seacoast. They are extensively cultivated in Central and Southern Europe, where they are more appreciated for food purposes than in the United States. However, the plant is

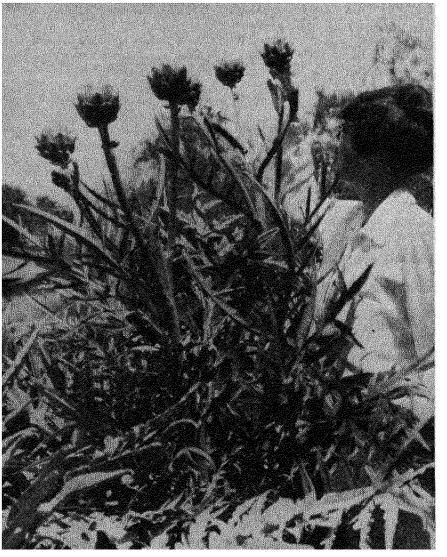


FIG. 167.—Leaves and inflorescences of the globe artichoke (*Cynara Scolymus*).

becoming more important in the South and in California. Artichokes are canned or used as a fresh vegetable.

Asparagus

Asparagus (*Asparagus officinalis*) is a native of temperate Europe and Western Asia, and still grows in a wild state in saline areas. It has been known and prized by epicures since Roman times and is widely grown and used throughout Europe. It was early introduced into the United States. The plant has perennial roots, which send up each year an erect branching stem several feet in height. Instead of true leaves, modified branches known as cladophylls occur. This is characteristic of the entire genus, which includes the so-called asparagus fern of the florists. The

axillary flowers are small and the fruit is a berry. The new shoots are very juicy and succulent, and these constitute the asparagus of commerce. If the shoots are allowed to develop, the plant soon becomes bushy and woody. Asparagus is an important truck crop, both for use as a fresh vegetable and for canning purposes. Although it can be grown under a wide range of soil and climatic conditions, it thrives best in fertile well-drained soil in moist temperate regions with an abundance of sunshine. It can be grown from seed or from year-old crowns. Once started, asparagus will continue to yield for 15 to 20 years. The shoots may be used either green or blanched. The former are more delicate and are usually eaten fresh, while the latter, which are thicker, are used chiefly for canning. For the best flavor asparagus should be cooked within 12 hours of picking. The food value is low, as the water content amounts to 94 per cent, but there is more protein present than in most vegetables. The pulp is sometimes dried, or canned as a paste. Asparagus has a definite medicinal value. Although widely grown for domestic use, it is a commercial product in only a few areas. California leads in the production of both green and canned asparagus. Other areas include: Massachusetts, South Carolina, Georgia, Illinois, and New Jersey.

Cabbage and Its Allies

One of the most ancient and most important herbage vegetables is the cabbage (*Brassica oleracea*). The wild ancestor, the colewort, a stout, weedy perennial of the seacoasts of Great Britain and Southwestern Europe, is still in existence. From this plant have arisen by selection or mutation the great variety of cultivated forms. Although best adapted to the Mediterranean type of climate, they will grow from the arctic to the subtropics. Cultivation of the cabbage is very old, and several varieties, true cabbage, cauliflower, and broccoli, were known to the Greeks and Romans. The ancient Germans, Saxons, and Celts were the first to grow cabbage in Northern Europe, and it became important at a very early date in Scotland and Ireland. Today the plants are grown the world over, except in the tropics. Cabbage is one of the best protective foods, for it contains the antiscorbutic vitamin and is also rich in sulphur. No other cultivated plant has varied so much. The commonest forms include the kales or

collards, Brussels sprouts, head cabbage, kohlrabi, cauliflower, and broccoli. In the kale and Brussels sprouts the stem of the first year is elongated, while in the others it is very short. These types will be discussed very briefly.

Kales and Collards (var. *acephala*).—These erect branching forms, which are also known as borecole or marrow cabbage, are closest to the wild form. They have numerous large broad leaves, which are used as a boiled green vegetable or for stock



FIG. 168.—A well-developed head of cabbage (*Brassica oleracea* var. *capitata*). (*Courtesy of the Massachusetts State College.*)

feed. Kale is grown more in other countries than in the United States. The plants are resistant to cold, heat, and drought. The giant cabbage kales of England reach a height of 8 or 9 ft. and the stout stems can be used for rafters or canes.

Brussels Sprouts (var. *gemmifera*).—In this variety the axillary buds on the erect stem develop little heads, instead of forming branches. These miniature cabbages are a favorite vegetable. Both tall and dwarf forms occur. Brussels sprouts are cool-season plants, and are more tender and delicate than cabbage.

Cabbage (var. *capitata*).—In the familiar cabbage the stem is so short that the great mass of thick overlapping leaves tends to form a head (Fig. 168). The older leaves surround the younger, smaller, more tender leaves and the minature stem, so that in section the cabbage resembles a huge bud. There are many varieties, some with smooth leaves and others with curled leaves. The latter, the Savoy cabbages, have the best flavor. Both green and red cabbages are grown. Cabbage is one of the best market garden crops in cool climates. It can be grown on heavy soil. The plant is very old and was introduced into England by the Romans. It is still so important in that country that it is often jokingly referred to as the national flower of England. Cabbage contains 91 per cent water, with some sugar and starch, considerable protein, and valuable lime salts. It is eaten raw (slaw) or cooked. Steaming is preferable to boiling for the nutrients are retained. Cabbage is not very easily digested. It is used for feeding stock and chickens. Sauerkraut is really human silage. Small pieces of cabbage are fermented in their own juice together with salt. Lactic acid bacteria act on the sugar to produce lactic acid, which is responsible for the sour taste. Sauerkraut originated in Asia and is now a favorite food in Russia and Germany, and in this country as well. In most European countries cabbage, in some form, is an important part of the daily diet of the poorer people.

Kohlrabi (var. *gongylodes*).—In kohlrabi no head is formed, but the short stem is transformed into a juicy mass of edible tissue, which stands out of the ground. It is large, spherical, and turniplike, white or purple in color, with large leaf scars. It is much used for human consumption abroad and by the foreign population of the United States. In this country it is used chiefly for stock feed. Kohlrabi is an early spring or fall crop, as it does not like the heat of summer. The kohlrabi is often considered to be a distinct species, *Brassica caulorapa.*

Cauliflower and Broccoli (var. *botrytis*).—In these forms a short erect stem is produced with an undeveloped inflorescence. The whole inflorescence forms a large head of abortive flowers on thick hypertrophied branches. The leaves are often tied around the mass of flowers to keep them white. In broccoli the heads are smaller and the leaves larger, and the whole plant is green. Cauliflower and broccoli are very old. They are more

delicate and easier to digest than cabbage, and are a favorite vegetable in all temperate regions.

Celery

Celery (*Apium graveolens*) is a native of temperate Europe from England to Asia Minor. In a wild state the plant is tough and rank with an acrid and poisonous juice. It grows in marshes, ditches, and other wet places. Under cultivation it is a biennial



FIG. 169.—Harvesting late celery (*Apium graveolens*). Note the way in which the rows are banked with dirt. This blanches the leaf stalks by preventing chlorophyll from developing. (*Courtesy of the Massachusetts State College.*)

forming a fleshy root and clump of compound leaves with long leafstalks (Fig. 169). These leafstalks constitute the celery of commerce. They are large and succulent, and their quality is much improved by blanching. This is done by placing boards, dirt, or paper around them to shut off the light and so prevent chlorophyll from developing. Celery requires a rich sandy loam and lots of water. It is grown in the south of the United States in winter, and in the north in summer. Commercial celery growing has become an important industry with an annual production of 8,000,000 to 9,000,000 crates. California, Michigan, Florida, and New York lead. Celery was formerly grown in the Old World for its foliage, which was used for flavoring and

as a garnish and for medicinal purposes. The roots are often boiled. The outer stalks, which are too tough to eat, are used as a basis for cream of celery soup. Celery seeds are grown to be used as a savory. The larger turniplike roots of a European variety, **celeriac** (var. *rapaceum*), are often used for soups and flavoring.

Chicory and Endive

The chicory (*Cichorium Intybus*) and the endive (*C. Endivia*) have been cultivated for over 1000 years, but are still very wild looking and show but slight effects of their association with man.

Chicory is a perennial with a long taproot, a coarse branching stem, and numerous basal leaves. The flowers are usually blue. The plant is a native of Europe, but is a common weed in the United States. It is much used abroad as a salad plant or for greens. The roasted root is an important adulterant of coffee.

Endive is a native of India. It was a favorite salad plant of the Egyptians and Greeks, and is grown today in every European country. It is becoming more important in the United States. The young basal leaves, which often have curled margins, are used as a salad. They are frequently blanched. The plant is an annual or biennial.

Lettuce

Lettuce (*Lactuca sativa*), a native of Southern Europe and Western Asia, is descended from the wild lettuce (*L. Scariola*), a common weed of roadsides and waste land in both the Old and New Worlds. It is another herbage vegetable of great antiquity. The Greeks cultivated three varieties, the Persian kings used it as early as 300 B.C., and the Moors developed many types, among them the present-day romaine. Nearly all the forms now grown seem to have been known in Europe prior to the Middle Ages. The plant produces a basal rosette of leaves, and later in the season a stalk with flowers and fruits. Lettuce has a milky juice. It is of little value as a food, except for its vitamins and iron salts. Several hundred varieties are grown. Formerly cultivated only in home gardens, lettuce is now an important commercial crop. It thrives best in a sandy or loamy soil and requires cool weather and not too much sun.

Among the principal types are head, cos, romaine, and cut-leaved forms.

Rhubarb

The succulent acid leafstalks of the rhubarb (*Rheum Rhaponticum*) are much used for pies and sauce. The plant is a native of Asia, where it still grows wild. It is a perennial with large rhizomes and produces early in each season a number of very large leaves, and, later, elongated flower stalks which bear dense masses of tiny whitish flowers. It is extensively cultivated as a food plant, and sometimes as an ornamental plant, in temperate portions of Europe and America. Rhubarb has nearly 95 per cent water with a little sugar and fat and salts of oxalic and malic acids. A wine is sometimes made from the juice.

Spinach

Spinach (*Spinacia oleracea*) is perhaps the commonest herbage vegetable used for greens. It is a native of Southwestern Asia and is widely cultivated in cool regions where there is an abundance of water. Early in the season it produces a large number of basal leaves, and later the flowering part. It is an annual, occurring in several forms. In addition to its use as a pot herb, spinach is now canned in large quantities.

Minor Herbage Vegetables

Among cultivated herbage vegetables of lesser importance may be mentioned Chinese cabbage (*Brassica pekinensis* and *B. chinensis*), an annual plant used for greens and salads; the dandelion (*Taraxacum officinale*), long popular for greens in a wild state, and now grown commercially; and water cress (*Rorippa Nasturtium-aquaticum*), an aquatic perennial much used for salads.

Many wild species are used by country people for pot herbs, particularly in the spring. The leaves of beets, turnips, and mustard are also utilized.

FRUIT VEGETABLES

Fruit vegetables are technically fruits, but they are rarely eaten in the raw state except in salads and usually require cooking. In other words, they are used as vegetables rather than as fruits.

In their food value and other properties they resemble the other vegetables.

Avocado

The avocado or alligator pear (*Persea americana*) is a small tree (Fig. 170) native to Mexico or South America and grown extensively in Central America and the West Indies for many

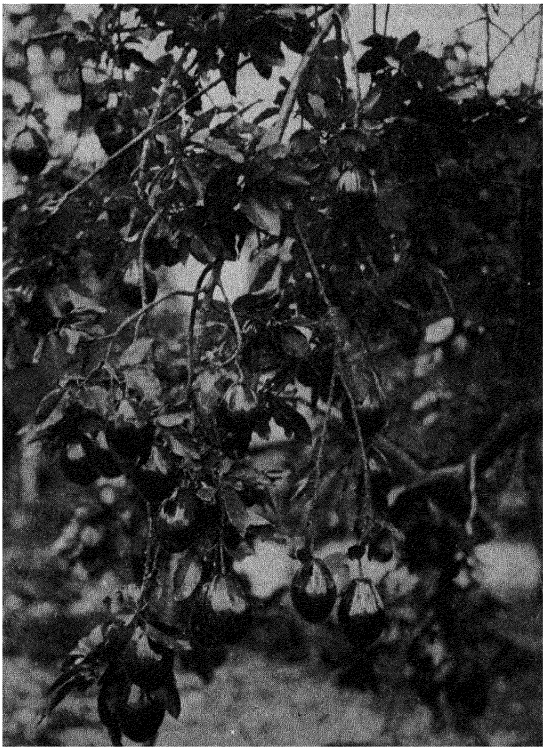


FIG. 170.—An avocado or alligator pear (*Persea americana*) in fruit.

years. The use of alligator pears is increasing in the United States and the plant is now of commercial importance in Florida and California. In the latter state they are often marketed as calavos. The brownish-green pear-shaped fruit, from 4 to 6 in. in length, is really a one-seeded berry. The pulp surrounding the large seed has a buttery consistency and contains 30 per cent fat, considerable carbohydrate material, and more proteins than any

other fruit. The vitamin content is also high. Over 500 varieties are known. Avocados constitute a valuable human food and may be eaten as a salad fruit or cooked.

Breadfruit and Jack Fruit

The **breadfruit** (*Artocarpus communis*) is one of the most important food fruits in the world. It is a native of Malaya, but is now

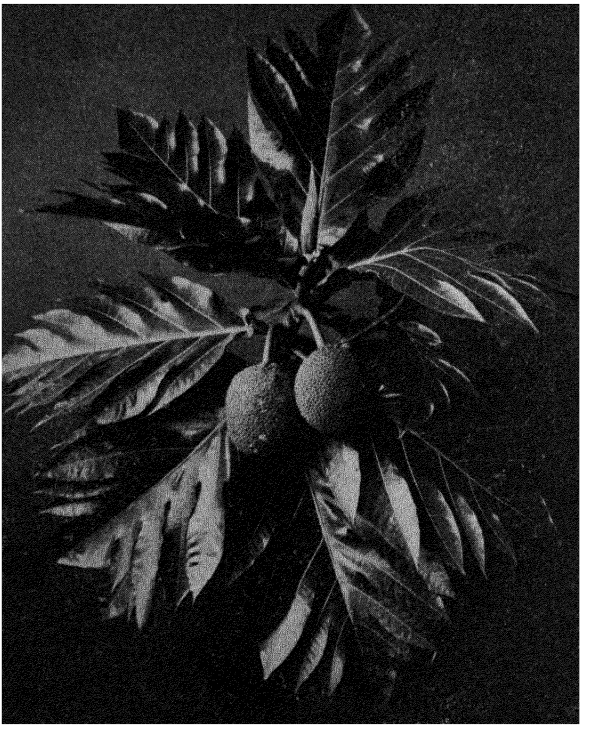


FIG. 171.—Leaves and fruit of the breadfruit tree (*Artocarpus communis*). The breadfruit is one of the most important fruits of the tropical world.

widespread in the tropics, particularly in Polynesia. It has been cultivated since antiquity. The tree is very handsome, reaching from 40 to 60 ft. in height, with deeply incised leaves. The prickly fruits (Fig. 171), which are about the size of a melon, are brownish yellow when ripe, with a fibrous yellow pulp. They are often borne in small clusters. The breadfruit is eaten fresh or

cooked. It is either baked, boiled, roasted, fried, or ground up and used for bread. During the few months when the fruit cannot be obtained, a paste that has previously been made is used. Over 100 varieties are known, some with seeds and others seedless. Few plants furnish a more wholesome food for man and beast, or have a greater yield. An eight-year old tree will produce between 700 and 800 fruits. The carbohydrate content is especially high.

The **jack fruit** (*Artocarpus integra*) has a similar use. It is an Indo-Malayan species, now widely dispersed in the tropics. The handsome tree reaches a height of 60 to 70 ft. It has entire leaves and huge fruits, 1 to 2 ft. long and weighing from 20 to 40 lb., which are borne on the trunk.

Chayote

The chayote (*Sechium edule*) is a trailing vine of tropical America, which produces a gourdlike fruit much prized as a vegetable. The pear-shaped fruits are technically pepos, berries with a spongy pulp and a hard firm rind. The plant is a perennial with large tuberous roots. Both the fruits and the tubers were among the principal foods of Aztecs, Mayas, and other primitive peoples of Central America. It has been grown in the Southern states for many years, but only recently has become of commercial importance. Chayotes grow vigorously and have a prolific yield. The plant has many uses. Not only are the tubers and fruits valuable for food, but the foliage can be used for greens or forage and the young shoots serve as a substitute for asparagus. The straw is valuable for making baskets and hats. It can also be grown as a bee plant or for ornamental purposes.

Cucumber

The cucumber (*Cucumis sativus*) is another gourd fruit, indigenous to southern India. It has been cultivated for 4000 years. The earliest writings of the Hebrews, Egyptians, Greeks, and Romans have numerous references to this plant. It had reached Europe by the seventeenth century and is now widespread. The cucumber is a rough-stemmed trailing vine with yellow axillary flowers and round to elongate prickly fruits. The water content is high, 96 per cent, so there is but little food value. The English forcing cucumbers have a smooth, usually seedless fruit, some-

times 2 ft. in length. Cucumbers are eaten raw, pickled, or cooked.

Pickles are made from small cucumbers or special varieties, such as the West Indian **gherkin** (*Cucumis Anguria*), which has tiny fruits with a thin flesh and numerous seeds. The fruits are soaked in brine tanks and treated with boiling vinegar. Sometimes spices, like dill, are added to give a special flavor. About 5,000,000 bu. are used for pickling. The northeastern United States is the center of the industry.

Eggplant

The eggplant or aubergine (*Solanum Melongena*) is a native of India, but is widely grown in tropical and subtropical regions, especially in the West Indies and southern United States. Several taxonomic varieties may be recognized. The plant is an erect branching herb, several feet in height. The fruit is a large, ovoid, whitish or purple berry about the size of a coconut. The plant is cultivated as an annual and requires a high temperature. The fruit is usually cut into slices and fried or broiled.

Okra

Okra (*Hibiscus esculentus*) is a native of tropical Africa. It was cultivated by Europeans as early as 1216 A.D., and has now been introduced into most warm tropics and subtropics. The plant is a stout annual, much resembling cotton in its habit. The young pods are very mucilaginous and are much used in soups under the name "gumbo," the Spanish word for okra. Okra is also cooked in various ways. It is often dried or canned. The stems and mature pods yield a fiber used in papermaking and for textiles.

Pumpkins and Squashes

Pumpkins and squashes are gourd fruits belonging to the genus *Cucurbita*. There is considerable speculation as to whether they are natives of America or Africa. The plants are coarse annual vines with large yellow flowers and fruits that rest on the ground. The numerous varieties are insect pollinated and readily cross.

Cucurbita Pepo may be native to Africa, but the American Indians were cultivating it at the coming of the white men. The long stiff stems and deeply incised leaves are usually prickly.

This species includes the field pumpkins, used for pies, canning, and cattle feed; the summer or crookneck squashes (Fig. 172); the scallop squashes, pattypans, or cymlings; vegetable marrows; and the small inedible gourds grown for ornamental purposes.

Cucurbita maxima with hairy round-lobed leaves is probably of American origin. This species includes the autumn and winter

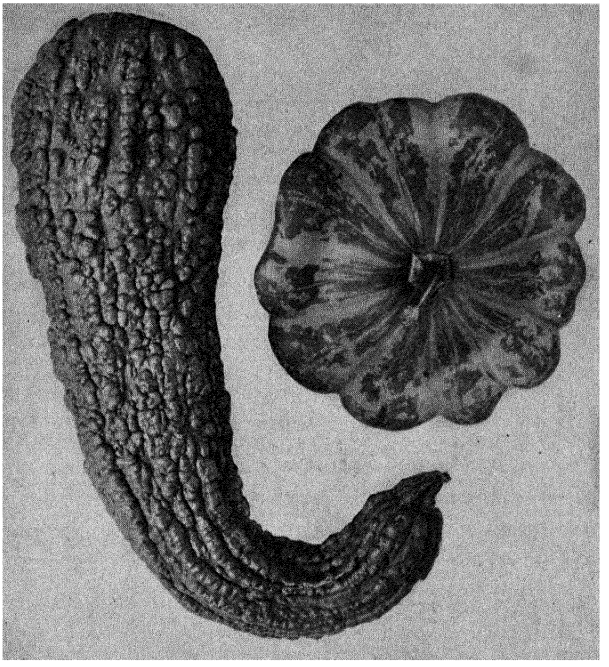


FIG. 172.—Two extremes of shape in the squash (*Cucurbita Pepo*). Left, a summer or crookneck squash; right, a scallop squash. (*Courtesy of Breck and Company.*)

squashes, such as the mammoth, Hubbard, and turban varieties.

Cucurbita moschata with pointed-lobed leaves is also American. It includes such autumn and winter varieties as the cushaw and cheese squashes.

Tomato

The tomato (*Lycopersicon esculentum*) is a native of Central and South America and still grows wild in that area. The

Spanish explorers carried the plant to Southern Europe where it was eaten for a long time before it was utilized by the people of Northern Europe and the United States. For many years it was considered to be poisonous, and was grown only for ornamental purposes under the names "tomatl," "love apple," or "*pomme d'amour.*" Tomatoes are coarse, branching, erect or trailing

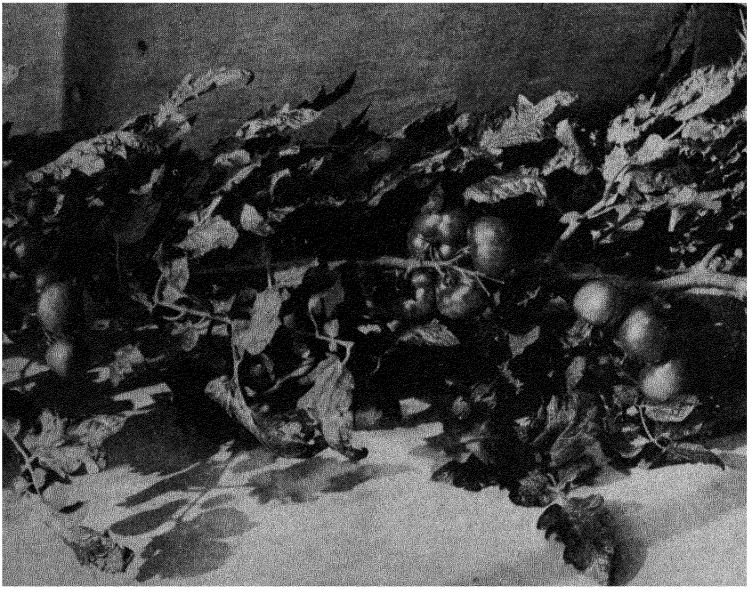


FIG. 173.—A fruiting spray of greenhouse trellis tomatoes (*Lycopersicon esculentum*). (*Courtesy of the Massachusetts State College.*)

herbs, with a true berry for a fruit (Fig. 173). They differ greatly in habit depending on the environmental relations and the kind, over 175 of which are grown. Several taxonomic varieties may be involved. The Mediterranean region and the United States are the most favorable regions for tomato growing. In California the plant is a perennial, but in the rest of the country it is grown as an annual. In the Northern and Central states the plants are started in a hotbed and later transplanted. Tomatoes are eaten raw or cooked, and are also preserved. The tomato canning industry is second to none, with a 1935 output of 647,640,000 cans. Only the pulp, which retains its characteristic flavor, is used.

The waste material, consisting of skins, cores, seeds, and unripe parts, was formerly discarded. This is now utilized and a fixed oil is expressed, which can be used for food, soap, or as a drying oil. The oil cake is of value as a stock feed. Ripe tomatoes are also used for chili sauce, ketchup, tomato juice, and tomato pastes, while green tomatoes are used for pickles and preserves.

CHAPTER XVIII

FRUITS OF TEMPERATE REGIONS

Ancient man must have learned early in his career to appease his hunger and eke out his existence by eating the numerous wild fruits, which everywhere attracted his attention. He soon became aware of the inedible nature of some of these fruits, and these he avoided. At first the nomadic tribes were content to gather in a region where the edible wild fruits were most abundant and to linger long enough to harvest them before moving on. Later man began to cultivate these fruits, choosing those with the best taste and the largest yield, as well as those which were easiest to grow. Finally, as civilization progressed and as the nutritive qualities and physiological action of these foods were studied, our present-day fruits were gradually developed. Most of the changes and improvements have been brought about by selection and hybridization. In many cases wild fruits are still used, both by primitive peoples and by civilized nations as well. In America the wild fruits used by the Indians were first cultivated after the advent of the white man.

It is interesting to note that a great many of the fruits grown today had their origin in the same part of Asia that was the earliest home of man. Thus from the very beginning man has had close contact with them, and his history has closely paralleled theirs. This is particularly true of the rose family, which includes a large number of our most familiar fruits, such as the apple, pear, cherry, plum, apricot, raspberry, blackberry, and strawberry. Apples and plums still grow wild in great profusion in the mountains of Central and Western Asia.

In his gradual dispersal over the surface of the earth man carried his food plants with him. He early reached the Mediterranean region, and here he found an area particularly well adapted for the growing of fruit. In this region, with its dry summers, its mild winters, and its fertile soil, a multitude of plants, once widely scattered, were brought together from their native homes and improved and perfected. Many varieties were known to the

Greeks, Egyptians, and Romans, and fruit growing was an important part of their civilization. The Dark Ages failed to wipe out the knowledge and experience gained by these ancient people, and, once revived, agriculture and horticulture have been carried on continuously in most of the regions with a high degree of perfection. Fruit growing is now carried on all over the world, often in areas not suitable for the cultivation of cereals.

Food Value of Fruits.—In temperate regions fruits are considered more as an agreeable addition to the diet than as a staple food. In the tropics, however, the reverse is true, and fruits may often be the chief, and even the only, source of food, as in the case of the banana, plantain, date, fig, coconut, and breadfruit. Our temperate fruits have only a slight nutritive value. The water content is about 80 per cent, and the remainder consists of cellulose, which may have some roughage value, and a solution of sugars, starches, pectin, and organic acids, flavored with essential oils and aromatic ethers. Carbohydrates are most abundant, the exact amount and kind of sugar being determined by the stage of ripeness. Fats and proteins are negligible. Organic acids, however, are present in greater amounts than in any other plant products. These are chiefly malic, citric, and tartaric acids. The various pectin compounds are important for they have the property of forming a jelly under proper conditions. Mineral salts are also present in considerable quantities.

Preservation of Fruits.—Because of their perishability, many ways of preserving fruits have been devised. These include drying, salting, and smoking; sweetening with sugar, honey, and spices; preserving in alcohol and chemicals; pickling in vinegar; packing in fats; and sterilization and canning. Some of these methods have been in use since the earliest time. The most important processes at the present time are drying, canning, and the use of sugar. Drying has long been a favorite method. Bacteria fail to develop when the water content is below 25 per cent. The common drying agents are the sun and hot air. Often the evaporation plants are on a huge scale. Some fruits are cooked with sugar before drying. Canning is of increasing importance, for both domestic and commercial purposes. A strong solution of sugar, honey, or glucose will also keep out agents of decomposition, and great quantities of fruit are preserved as jams, jellies, marmalades, and candied fruits. However, the

development of improved cold-storage methods and increased facilities for transportation in recent years have made it possible to use fresh fruit to a greater extent than ever before. Today the production of fresh fruit has become an important industry, and it is possible to draw on all parts of the world for the supply, which is virtually unlimited. Of the thousands and thousands of edible fruits only about 100 are cultivated, and of these not more than 50 per cent reach the Northern markets.

Classification of Fruits.—The classification of fruits is very varied. Technically a fruit is the seed-bearing portion of the plant, and consists of the ripened ovary and its contents. Usually the ovary alone is involved in the formation of the fruit, but in the accessory fruits other structures, such as the calyx and receptacle, are involved. Simple fruits are derived from a single ovary, and compound fruits from more than one. In the latter case the aggregate fruits are formed from numerous ovaries of the same flower, while multiple fruits come from the ovaries of different flowers. All these may be either dry or fleshy. In our discussion of food plants we have already considered the edible dry fruits; the grains, legumes, and nuts; and also certain fleshy fruits that are usually classed as vegetables. The present chapter will be concerned only with those fruits which are usually eaten without cooking, to which the term "fruit" is restricted in common usage. For convenience the fruits of temperate regions will be considered first, followed in the next chapter by the more important of the tropical fruits.

POME FRUITS

The pome fruits are simple accessory fruits in which the ovary is surrounded by a fleshy outer portion derived from some other part of the flower. Authorities differ as to the morphological nature of this edible portion. Some consider it to be a fleshy calyx, but the most recent studies indicate that it is an enlarged receptacle. In either case the ripened ovary forms the core only. In most of the pomaceous fruits the flesh entirely surrounds the carpels, but in the medlar the carpels are exposed at the top. Although the word "pome" is restricted to this type of fruit, "pomology" retains its original Latin significance and refers to the whole subject and practice of fruit growing.

Apple

The apple (*Pyrus Malus*) occupies the first place among fruits of temperate regions in importance and extent of cultivation. It is a native of Eastern Europe and Western Asia and has been grown for over 3000 years. Apple seeds have been found in the remains of the Lake Dwellers. Twenty-two kinds were known to the Romans, and today there are over 6500 horticultural forms. This great number is due in part to the readiness with which apples hybridize and to their great variability.

The apple is a low round-crowned tree rarely exceeding 40 ft. in height. It may reach an age of 100 years. The wood is hard and dense and is used for tool handles and firewood. The attractive pink and white flowers and the leaves are borne together, usually at the ends of short twigs, known as spurs. Apples are adapted to many different soils and climates. The best yield is obtained where the soil contains a slight amount of lime. Although apples are hardy and can be grown as far north as 65°N.L., they are subject to frost injury. They are not grown in the tropics. North America, Western Europe, Australia, New Zealand, and South Africa are the chief apple-producing regions.

The apple was brought to America by the early colonists as soon as it was found that the native species were of little value. By 1750 there were many well-established orchards. At the present time apples are grown from Nova Scotia to Georgia and west to the Great Plains, and from the Rocky Mountains westward, except in the Southwest. They can be grown from seed, but they are usually propagated by grafting or budding. Summer, fall, and winter varieties (Fig. 174) are cultivated. Washington, New York, Pennsylvania, California, Virginia, Michigan, Ohio, and Oregon lead in production in the order named. Canada is also a large producer. In 1935, 168,465,000 bu. were grown in the United States, about half of which were consumed locally. Apples are picked when fully ripe in order to allow ample time for all the chemical changes that take place during ripening. These involve an increase in the amount of sugar and a corresponding decrease in starch and acidity.

Until the end of the last century apples were practically the only fresh fruit available from November to June. This was due to their exceptional keeping qualities. Apples are dried in large

quantities, as well as eaten raw and cooked. The juice is converted into cider and vinegar. The sugar in fresh apple juice is readily changed into alcohol by the action of wild yeasts. When the alcoholic content is at its maximum, hard cider is the result. Later acetic acid bacteria convert the alcohol into acetic acid or vinegar. Applejack is an alcoholic beverage made from cider.

Crab apples produce a small yellowish or reddish fruit about 1 in. in diameter. Although there are several native American



FIG. 174.—Fruiting branches of a Baldwin apple tree (*Pyrus Malus*). (*Courtesy of the Connecticut Agricultural Experiment Station in New Haven.*)

species, their fruits are of little value, and they are rarely grown, except for their attractive flowers. The crab apples of cultivation are usually hybrids between the common apple and the Siberian crab apple (*Pyrus baccata*). Many oriental species have been introduced for ornamental purposes and are grown for their showy flowers.

Pear

The **common pear** (*Pyrus communis*) is likewise a native of Eurasia, and it was known to all the ancient peoples. It resembles the apple in general appearance, although it is taller and more upright. The flowers are usually white and appear

with the leaves. The characteristic pyriform fruit (Fig. 175) has a persistent calyx. The pear is sweeter and more juicy than the apple, and the flesh contains numerous grit or stone cells, a specialized type of cell with exceedingly thick walls. Pears are less hardy and have a more restricted range. They prefer heavy soils with considerable humus and good drainage and regions with a fairly equable climate, such as occur near large bodies of water.

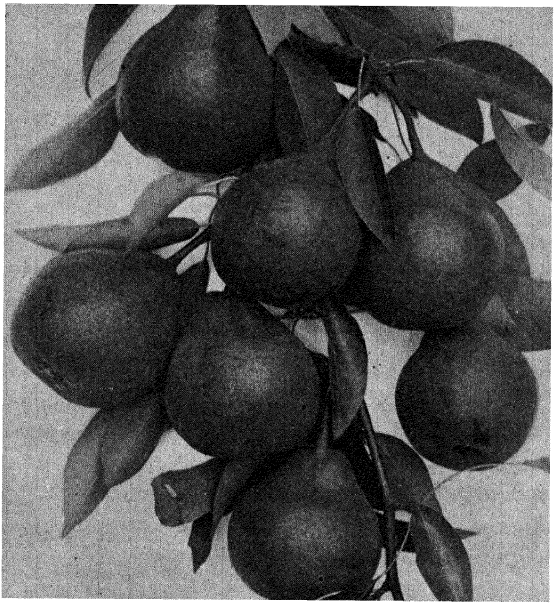


FIG. 175.—A fruiting branch of the pear (*Pyrus communis*). (*Courtesy of Breck and Company.*)

They are propagated from seed and by grafting. Pears are extensively grown in Europe, where over 5000 kinds are recognized. France is the leading country. Pears are picked by hand before they are fully ripe. The European pear is the source of most of our eating pears.

The **Chinese** or **sand pear** (*Pyrus serotina* var. *culta*), the source of most of the varieties grown in this country for cooking purposes and storage, is a native of China. The flowers appear just before the leaves. The large fruit has a deciduous calyx and a very gritty, hard flesh with excellent keeping qualities. This pear is frequently used in hybrids and grafting with the common pear.

In 1935 the United States produced 21,255,000 bu. of pears. California, Washington, Oregon, and New York are the leading states. There is a large export trade with Europe. Pears are used for table fruits and great quantities are canned. A beverage, perry, similar to cider is made from the juice.

Medlar

The medlar (*Mespilus germanica*) is a small tree with spreading branches borne at right angles. It is a native of Europe and several varieties are cultivated, chiefly in England. The brown apple-shaped fruit has a harsh flesh and rather acid taste. It is used for jams and jellies, and somewhat as a table fruit.

Quince

The quince (*Cydonia oblonga*) has also been cultivated from very ancient times. It was much esteemed by the Romans. It is a native of Western Asia from Persia to Turkestan, and still grows wild. In spite of its long cultivation it has been but little changed from the wild form. It is a small tree from 15 to 20 ft. in height with many crooked branches. Under cultivation it is sometimes a large bush. The fruit is round or pear shaped and quite large. The leaves are densely tomentose beneath, and even the fruit is wooly when young. The golden-yellow flesh is hard and rather unpalatable. The seeds have a mucilaginous covering and are of value in medicine. The fruit is rarely eaten raw, but is used for jelly and marmalade, often combined with apples and pears. It is also canned. The chief producing states are California, Ohio, Pennsylvania, and New York.

STONE FRUITS

The stone fruits or drupes are fleshy fruits with a single seed enclosed in the hard inner portion of the ripened ovary wall. There are three regions in the fruit: the outer skin or epicarp; the fleshy edible mesocarp; and the stone or endocarp, which contains the seed. Most of the drupaceous fruits of temperate regions belong to the genus *Prunus*. They are trees and shrubs, which often exude a natural gum. The leaves, bark, and seeds contain a glucoside, amygdalin, which is readily converted to prussic acid and may cause poisoning. The stone fruits and pome fruits are often classed for horticultural purposes as orchard fruits.

Apricot

The apricot (*Prunus Armeniaca*) is a native of Asia, where it still grows wild over a wide area. It was cultivated in China as early as 2000 B.C., and soon reached India, Egypt, Persia, and Armenia. It was introduced into Europe in the first century. The apricot is a small tree 20 to 30 ft. in height with pink flowers produced before the leaves. The fruit, which is peachlike in color and shape, is velvety when young and has a yellowish-orange flesh. The stone is smooth and flattened. The apricot is susceptible to frost and is grown only in warm temperate regions, chiefly in China, Japan, and Northern Africa. In the United States 95 per cent of the crop is grown in California. In 1935, 191,000 short tons were produced. Apricots are used as a table fruit in the regions where they are grown. They are also dried, canned, candied, and made into a paste. A substitute for almond oil is expressed from the seeds.

Cherry

The cherries are trees with a birchlike bark, white or pinkish flowers produced in clusters, and small, smooth, long-stemmed fruits with a round smooth stone. They are natives of Eurasia and were cultivated long before the Christian era. They have been grown in the United States since colonial times. The several hundred varieties in cultivation are referred to two distinct species. The fruits of the native American cherries are of no commercial value.

The **sweet cherry** (*Prunus avium*) is a tall long-lived tree with yellow or greenish fruit. It has a rather restricted range in this country and is grown only in regions with an equable climate, such as New York, the Lake States, and the Pacific coast. There are some 600 varieties in cultivation.

The **sour cherry** (*Prunus Cerasus*) is a smaller tree, with a heavy wood and red fruits. It is grown in the Atlantic States and westward to the Mississippi valley. New York and Michigan lead in the production of sour cherries, which are used chiefly for canning purposes. Three hundred varieties are grown.

Cherries are used as table fruits, in pies, for glacé fruits, and in canning. For the last purpose they are often bleached in fumes of sulphur and treated with brine and sodium sulphite to harden the flesh. Cherry brandy or kirschwasser and mara-

schino are distilled from cherry juice. Maraschino cherries are grown in Dalamatia. The juice is also used for syrup, cherry cider, and jelly. A fixed oil can be obtained from fresh seeds.

Cherries are widely grown in temperate regions, and are especially important in Italy and other Southern European countries. The United States in 1935 produced 117,430 small tons. New

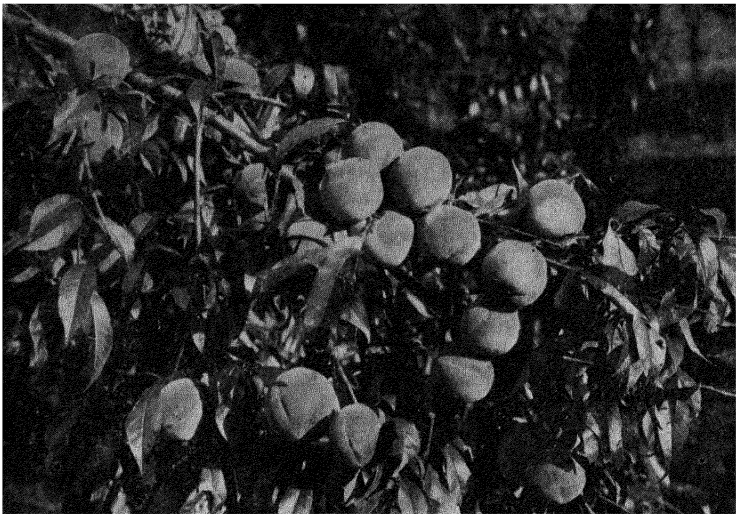


FIG. 176.—Leaves and fruit of the peach (*Prunus Persica*) (*Courtesy of Breck and Company.*)

York, Michigan, California, Washington, and Oregon are the leading states.

Several species of Japanese flowering cherries, chiefly *Prunus serrulata*, are cultivated for ornamental purposes.

Peach

The peach (*Prunus Persica*) is the second most important fruit in the United States. The tree is a native of China, where it has been grown for thousands of years. Numerous varieties have been developed there, and many legends have sprung up in regard to the fruit. The peach reached the Mediterranean region very early in history and the Romans knew at least six kinds. It was brought to the United States by the early colonists. Today it is cultivated in most temperate countries, particularly in Southern

Europe, the United States, South Africa, Japan, and Australia. Between 2000 and 3000 varieties are grown, few of which reach the markets.

The peach is a low tree, rather short-lived and susceptible to frost injury and low temperatures. The attractive pink flowers are produced before the leaves. The round fruits (Fig. 176) have a velvety skin and a compressed, pitted or furrowed stone. The peach does best in a sandy soil. The commercial orchards are usually near water. In 1935, 52,380,000 bu. were grown, with California, Georgia, Michigan, New Jersey, Pennsylvania, New York, and Washington leading in production.

Peaches are a favorite table fruit. However, they are very perishable and so are hard to transport and store. Large numbers are dried and canned. Both fixed and volatile oils, akin to almond oils, are obtained from the seeds. During the war peach stones were used as a source of charcoal for gas masks.

Nectarines (var. *nectarina*) are bud variations of the peach. They have a smooth skin and are smaller, and are grown west of the Rocky Mountains.

Plums and Prunes

Plums are shrubs, or small trees, with white flowers and large, smooth, clustered fruits with a bloom. The smooth stones are flattened. The commercial plums of the United States are derived from three main sources: the European plums, native American species, and Japanese species. These three types have such diverse climatic requirements that plums of some sort can be grown all over the United States and well into Canada, except in the colder regions.

European Species.—The European plum (*Prunus domestica*) is a native of Eurasia and still grows wild in that region. It has been cultivated for more than 2000 years, and was known to the Lake Dwellers and the Greeks and Romans. Today it is the best known and most widespread of all the plums. It was brought to America by the colonists, and is now grown on the Atlantic and Pacific coasts and in the Lake States. It is a large tree, 30 to 40 ft. in height, with variously colored fruits. Over 900 varieties are cultivated, particularly in Europe. These include the green gages, egg plums, and prunes. *Prunus insititia*, a smaller and more hardy plum, has also been grown for over 2000 years and occurs

wild in Europe and Asia. It includes the damson and bullace plums. Another variety, the sloe (*P. spinosa*) is much used in Europe in making liquors.

American Species.—The various American plums have been derived from native species in recent times. They are hardy and

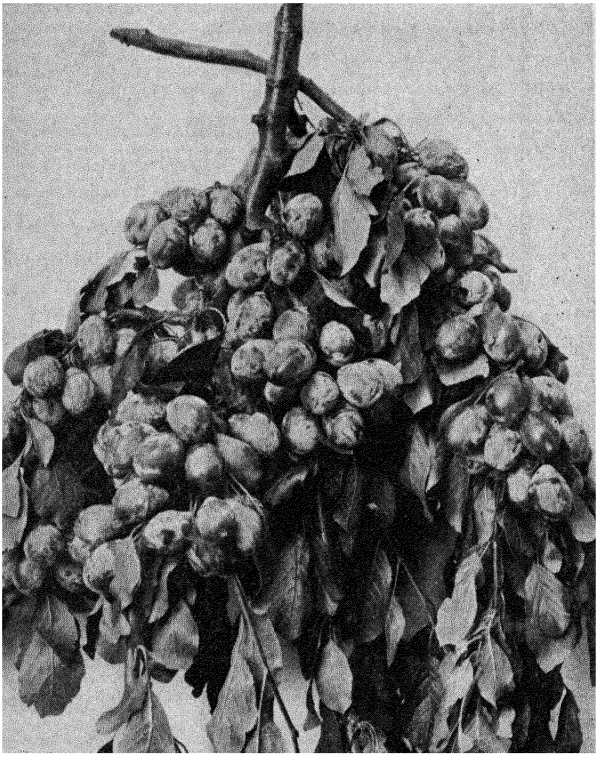


FIG. 177.—A branch of California prunes (*Prunus domestica*). (*Courtesy of Ginn and Company.*)

are grown in the Mississippi valley and in the South, where the European types do not thrive. Several species have been domesticated, chiefly *Prunus americana*, with some 260 forms, *P. hortulana*, and *P. nigra*. The fruits of the last two species are small and not very palatable, and so are used chiefly in preserves and marmalades.

Japanese Species.—*Prunus salicina* and other Japanese species were introduced into California at the end of the last century.

Nearly 100 new varieties and hybrids have been developed by Burbank and others. These plums are not much used but they have a wider range of cultivation than even the European types.

Plums are used for fresh fruit, cooking, canning, and jams. They are picked when mature, but not quite ripe, if they are to be used as table fruit. For use in canning and jams they are allowed to ripen longer, and for prunes they must be fully ripe. The 1935 production of plums was 104,425 tons, 75 per cent of which was produced on the Pacific Coast.

Prunes.—Prunes are plums with a high sugar content, and can be cured without removing the stone. Large fruits (Fig. 177) of European varieties are picked carefully and the skin is ruptured They are then dried, either in the sun or by artificial heat, after which they are allowed to "sweat" for a few weeks, and are finally graded and "glossed." This process, which consists of heating in steam or salted boiling water, glycerin, or fruit juice, gives a glossy appearance to the surface and also sterilizes the skin. The prune industry is a very important one on the Pacific Coast. The 1935 production of dried prunes was 280,000 short tons. California alone has 6,500,000 trees and produces from 300,000,000 to 400,000,000 lb. annually. Jugoslavia and France also produce prunes in large amounts.

GOURD FRUITS

The gourd fruits are trailing tendril-bearing herbs, often of great size. The fruit is a pepo, a modified berry with a hard and firm rind. They include several edible forms, such as the squashes, pumpkins, and cucumbers, which have already been discussed under fruit vegetables; the melons and watermelons; and the ornamental gourds.

Melons

The melon (*Cucumis Melo*) probably originated as a wild plant in Southern Asia. It is very old and was known to the Egyptians and Romans. The melon reached Europe in the seventeenth century. It is now cultivated in most warm temperate countries. Several kinds of melons are grown.

The netted or nutmeg melon is the type grown to the greatest extent in the United States. It is also called muskmelon and, erroneously, cantaloupe. This melon has a soft rind and netted

markings on the surface. There are many varieties, one of which is the Rocky Ford, a melon with delicious taste and odor, which was first grown under irrigation in Colorado. The true cantaloupe is a European melon that is not grown in America. It has a hard warty rind and dark yellow flesh. The winter melons, such as the casaba and honeydew, are larger, smoother, and more spherical types. They require a longer season for ripening, but have good keeping qualities.

Melons as a rule require a fertile soil and long growing season, with a high temperature and plenty of moisture and sunlight. Muskmelons are nearly ripened on the vines, as this increases the sweetness and flavor. The winter melons are ripened in storage. The leading melon-producing states are New Jersey, Maryland, North Carolina, Georgia, Arizona, Colorado, Arkansas, and California. In the cooler parts of the country melons are grown under glass.

Watermelon

The watermelon (*Citrullus vulgaris*) is a native of tropical Africa, where it has long been used by the wild tribes. It has been cultivated for centuries and reached India and Egypt very early in history, as evidenced by its having a Sanskrit name and figuring in Egyptian paintings. It is still important in these countries, and also in Southern Europe and central and southern United States. The watermelon is an annual plant with extensive vines, which may cover a whole field, and large fruits that may weigh 50 lb. or more. The reddish or pink pulp is very sweet and juicy, with white or black seeds. The varieties differ in the shape of the fruit, its color, and the thickness of the rind. The plant requires a fertile sandy soil with abundant sunshine. The fruits are picked when fully ripe and stand shipment well. In 1935 the United States grew 57,254,000 watermelons.

A variety (var. *citroides*) with a white, more solid flesh is called the **"citron"** or preserving melon. It is used in jams, jellies, and preserves, and, because of its high pectin content, is added to fruit juices that do not jell readily. This plant must not be confused with the true citron, which is one of the citrus fruits.

GRAPE

Although technically a berry, the grape is so different in appearance and of so much more importance than the other berries that

it warrants special consideration. Grapes grow wild in many temperate portions of Europe, Asia, Africa, and America. They must have been widely dispersed by birds even before the existence of man. The cultivated grapes of the present day have been derived from European and American species.

The **European** or **wine grape** (*Vitis vinifera*), the "vine" of the ancients, is one of the oldest of cultivated plants. It probably originated in the Caspian Sea region of Western Asia. Grapes are frequently mentioned in the Bible. They have been grown in Egypt for 6000 years, and were highly developed by the Greeks and Romans. They spread all over Europe with the Roman civilization, and now are found in all temperate regions. The grape is a woody, climbing, tendril-bearing vine with large palmate leaves; small, insignificant, sweet-smelling flowers; and large clusters of fruits. The European grape has ellipsoidal fruits with a rather solid flesh, a high sugar content, and a skin that does not slip off the flesh readily. In nature the vines grow rapidly and reach a considerable length, but in cultivation they are pruned back until they are short stout stumps, 3 or 4 ft. in length. Grapes require a loose, well-drained soil, and hillsides are often utilized. They are usually propagated by cuttings. The European grape is the source of most of the wine grapes. It is common all over Europe, especially in the Mediterranean region. This species is very susceptible to various fungus and insect pests, particularly the root louse (*Phylloxera*), which at one time threatened the very existence of the grape industry. Fortunately the American grapes are not so susceptible and they are now used as stocks on to which the European varieties are grafted. *Vitis vinifera* was introduced into the United States as early as 1616 by Lord Baltimore but it did not thrive. In spite of many attempts it has never been grown successfully in the eastern part of the United States, owing probably to its susceptibility to cold and pests. The story is different west of the Rocky Mountains and the growing of the European grape has become one of the chief industries, particularly in California. This grape is used for wine, for raisins, for cultivation under glass, and as a table grape, for it has good keeping qualities.

There are several **native American grapes** that have been domesticated, and numerous horticultural varieties of these are grown in the Eastern states. Hybrids between these native species and the wine grape also occur. The northern fox grape

(*Vitis Labrusca*) of the eastern United States has given rise to the greatest number, including such well-known types as the Concord, Catawba, Delaware, and Niagara; the muscadine grape (*V. rotundifolia*) has given rise to the scuppernong, a variety extensively grown in the South. *V. vulpina* and *V. aestivalis* are also in cultivation. The American grapes (Fig. 178) are larger and more hardy than the European. The fruit is round with a more watery flesh and a skin that slips off very easily. They are used

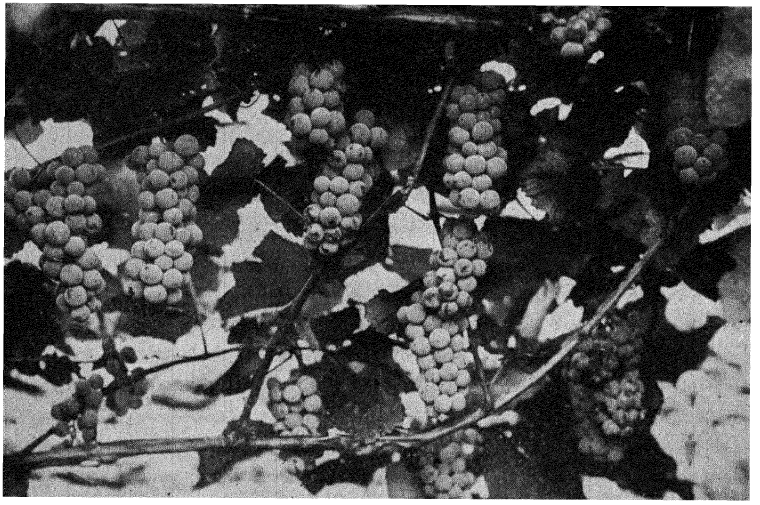


FIG. 178.—Clusters of Sheridan grapes. This variety may be a hybrid between *Vitis Labrusca* and *V. vinifera*. (*Courtesy of the Connecticut Agricultural Experiment Station in New Haven.*)

for eating and for making grape juice, jams, and jellies. Wild grapes are harvested extensively and by many people are preferred to the cultivated forms as sources of jelly.

Grapes are the source of raisins and the dried currants of commerce. **Raisins** are dried grapes, prepared from wine grapes with a high sugar content and firm flesh. Both seeded and seedless varieties, like the Sultana, are marketed. The best quality is used for table raisins, which are merely dried in the sun. Cooking raisins are prepared from poorer grades and treated with lye and sulphur before drying. In the United States all the raisins are produced in California.

Currants are small dried grapes prepared from a variety that grows in Greece. It is a very old type, dating back as far as 75 A.D. Currant growing has always been an important industry in Greece.

In recent years most of the waste products of the grape industry have been utilized in some way. Fertilizers, stock feed, acetic acid, cream of tartar, a fixed oil, and tannin are all prepared from one part or another of the fruit. Grapes are sometimes grown for ornamental purposes, and the wood has some value.

The chief grape-growing countries are Europe, the United States, Argentina, Chili, Australia, and South Africa. The United States produced 2,326,680 short tons in 1935, with California, responsible for 2,065,000 short tons. New York, Michigan, Ohio, and Pennsylvania are the other leading states.

BERRIES

The term "berry," as in the case of "nut," "fruit," and "vegetable," is used in several senses. Technically a berry is a thin-skinned one-celled fleshy fruit with seeds scattered through the flesh. According to this definition the tomato, grape, eggplant and many other fruits are berries, while such fruits as the strawberry, raspberry, and blackberry are not berries at all, but rather aggregate compound fruits. For the purposes of the present discussion the term will be used to include the common bush fruits, or berries, of cultivation and the mulberry as well. In nearly all these fruits wild plants serve as an important source of the crop today, just as they have from time immemorial, and the cultivated forms have been domesticated in comparatively recent years. It will obviously be impossible to list all the species involved in the several cases.

Blackberries and Raspberries

The blackberries and raspberries belong to the genus *Rubus* which includes many species and a vast number of hybrids Comparatively few are of economic importance.

The **blackberries** or brambles are erect, decumbent, or creeping shrubs, usually armed with thorns and prickles. The erect "canes" die down to the ground every few years and are renewed from the rootstalks. The velvety black fruits are aggregate fruits, consisting of numerous ovaries of the flower ripened into

small drupelets (Fig. 179). When picked the fruit does not separate from the somewhat fleshy receptacle. Although blackberries can be grown anywhere except in regions with severe winters or extreme heat or drought, they are nowhere of great importance. The blackberry is almost entirely an American

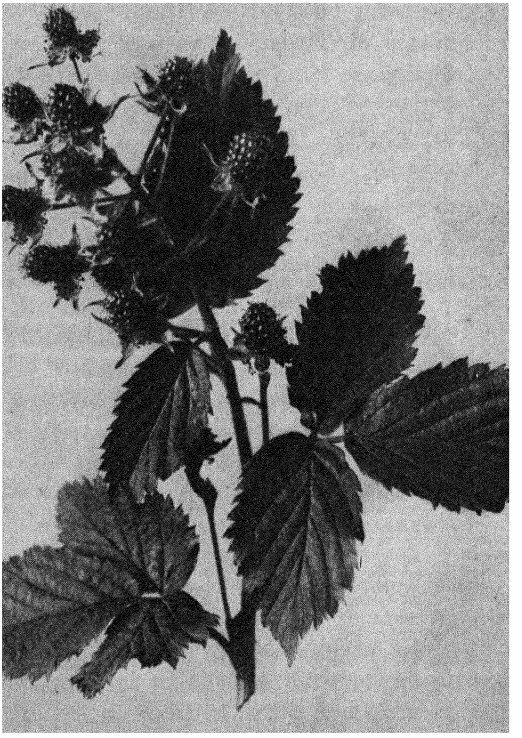


FIG. 179.—Leaves and young fruits of a blackberry. (*Courtesy of the Massachusetts State College.*)

fruit. The cultivated forms have been derived chiefly from *Rubus alleghaniensis*, *R. argutus*, and *R. frondosus*. Trailing species are known as dewberries, and these include *R. flagellaris*, *R. trivialis*, and *R. vitifolius*. Blackberries are used fresh and for jams, cordials, preserves, and canning.

The **loganberry** (*Rubus loganobaccus*), which originated in California, has very large fruits, but is rather poor in flavor. It is grown for canning purposes, both the fruit and the juice being

used. The loganberry is usually considered to be a hybrid between a blackberry and a raspberry, but it may be a distinct species, or a horticultural form of *R. vitifolius.*

The **raspberries** are smaller shrubs, usually with a vigorous, erect, bushy habit. They have small prickles or bristles. The aggregate fruit separates from the receptacle when ripe, thus leaving a cavity on one side (Fig. 180). The black raspberries are derived from *Rubus occidentalis* of eastern North America, while the red raspberries come from *R. idaeus* of Europe, or its American

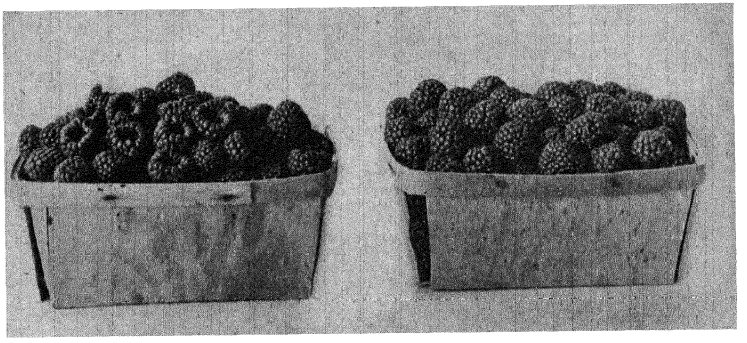


FIG. 180.—Red raspberries ready for market. (*Courtesy of the Massachusetts State College.*)

var. *strigosus.* The European species has been cultivated from great antiquity and was highly esteemed by the Greeks and Romans. The raspberry is one of the hardiest of fruits and can be grown as far north as Alaska and northern Canada. It is used fresh or cooked, and is utilized for jams, jellies, vinegar, and as a flavoring material. Large quantities are canned.

Blueberries and Huckleberries

Wild plants are still the source of most of our supply of blueberries and huckleberries. These plants are low ericaceous shrubs, common on acid soil throughout eastern North America. In the huckleberry the fruit is a berrylike drupe, while in the blueberry it is a true berry. The former occurs only in the wild state, with *Gaylussacia baccata* the chief species. Blueberries have been cultivated in recent years in the sandy acid soil of coastal New Jersey with a remarkable increase in size and yield over the wild fruit. In the so-called blueberry barrens of Maine and

adjacent New Brunswick the plants are so abundant in the sterile acid soil that they can be subjected to a crude sort of cultivation. The yield is kept up by frequently burning over the area, and, if other shrubs are kept out, an almost pure stand of blueberries results. Often the berries are so numerous that they can be harvested with a cranberry rake. The industry is of



FIG. 181.—Fruiting spray of a high-bush blueberry (*Vaccinium corymbosum*). (*Photo by F. M. Dearborn.*)

increasing importance in Maine and in many places even forested areas are being cut over and converted into blueberry land. Blueberries are eaten fresh or cooked, chiefly in pies, and large quantities are canned. The principal low-bush species are *Vaccinium canadense, V. pennsylvanicum,* and *V. vacillans;* the high-bush species of most importance include *V. atrococcum* and *V. corymbosum* (Fig. 181).

Cranberries

Cranberries are low trailing woody plants, characteristic of bogs and wet acid soil throughout northeastern North America and Northern Europe. The fruit is a true berry. The American

cranberry (*Vaccinium macrocarpum*) has been an important cultivated plant since 1840. It is grown in sandy bogs, which can be flooded during the winter and spring. The berries are picked with a scoop, the cranberry rake, and foreign material is removed by winnowing. Cranberry growing is an important industry in Massachusetts, New Jersey, and Wisconsin, and to a lesser extent in other states. Wild plants of this species, and the smaller *V. Oxycoccus*, furnish some fruit for home consumption. The smaller highland or mountain cranberry (*V. Vitis-Idaea*) with a firmer, more spicy fruit is abundant in Northern Europe and is highly esteemed in Scandinavian countries; the American form (var. *minus*), a boreal and arctic-alpine species, is equally desirable.

Currants and Gooseberries

Currants and gooseberries are usually classified in the genus *Ribes*, although the gooseberries are sometimes segregated in *Grossularia* by some authorities. They are low bushy plants, very hardy, and well adapted to cold climates. The currants are usually smooth with the flowers and fruits in racemes (Fig. 182). In the gooseberries the stem is usually armed with spines or prickles, and the flowers and fruits are solitary.

Currants are native to both the New and the Old Worlds. The common red and white currants (*Ribes sativum*) are natives of Eurasia. They have been grown in Europe since the Middle Ages, and were early brought to America, where they have become naturalized in many places. Several varieties are grown, chiefly for domestic use, and the plants are likely to suffer from neglect for ordinarily they are allowed to take care of themselves. They attain their best development in cool humid regions. The European black currant (*R. nigrum*), also a native of Eurasia, is but little grown in the United States. There are several wild species in America with edible fruit, the most important of which is *R. americanum*. Currants are too acid to make a good table fruit, but are much used for jams, jellies, sauces, pies, and wine.

The **European gooseberry** (*Ribes Grossularia*), another species of Eurasian origin, is grown in the cooler parts of both Europe and America. The tart round fruits may be red, yellow, green, or white, and hairy or smooth, depending on the variety. Goose-

berries were formerly much more important than they are today. The most important native American species is *R. hirtellum.*

Mulberry

The mulberry is not a berry in any sense of the word. It is a multiple accessory fruit derived from a whole inflorescence. The

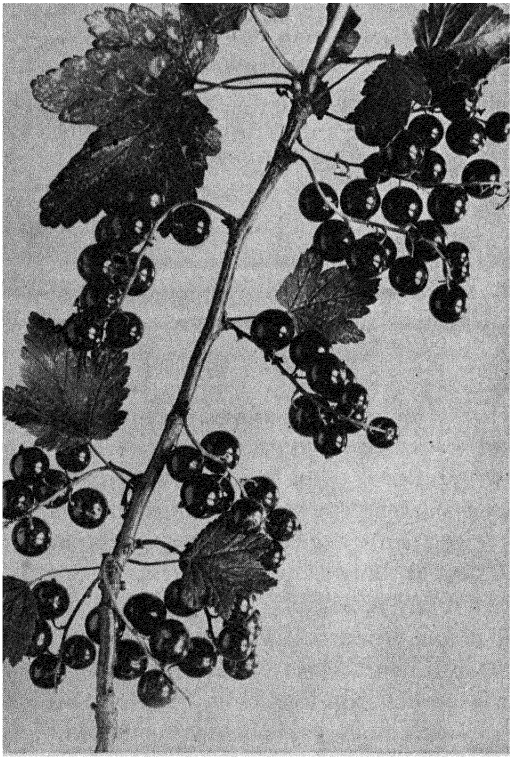


FIG. 182.—Leaves and fruit of the red currant (*Ribes sativum*). (*Courtesy of the Massachusetts State College.*)

actual fruits, little achenes or nutlets, are surrounded by the fleshy sepals and grouped together with the fleshy axis to form the so-called syncarp. The mulberries are trees native to both Asia and America. The fruits are very juicy and are much eaten in some parts of the world. They also afford valuable food for animals, particularly hogs and poultry.

The black mulberry (*Morus nigra*), an ornamental tree 40 to 60 ft. in height, is a native of Asia Minor and Persia. It has been cultivated for a long time. Mulberries are frequently mentioned in the Bible, and the tree was familiar to the Greeks and Romans. It reached Europe in the twelfth century, and is now naturalized in both Europe and America, where it is planted chiefly in the Southern states. The fruit is black or dark red, and is used as a dessert fruit.

The red mulberry (*Morus rubra*), the largest of the genus, is a native of eastern North America. The bright red or blackish fruits are not much eaten, except by animals. The wood, however, is valuable.

The white mulberry (*Morus alba*), with white or pinkish fruits, is a small tree. It is much less hardy than the other species. It is a native of Asia and was introduced into both Europe and America for its leaves, which serve as food for the silkworm. The fruits are of but little value. In Europe the wood is used and a yellow dye is obtained from the roots.

Strawberries

The strawberry is one of the most important of the small fruits and is a favorite in all temperate countries. Its only drawback is its perishable nature. The fruit is not a berry, but an aggregate accessory fruit, consisting of a number of small dry achenes embedded on the surface of a large fleshy receptacle. The strawberry (Fig. 183) is a low perennial herb with a very short thick stem and trifoliate leaves. It produces numerous runners, which root at the tip and are used to propagate the plant. Strawberries have been grown in Europe since the fourteenth century, and in America since colonial days. They need only good soil, a temperate climate, and lots of sunshine, and so are widely grown. In the United States their cultivation has been of commercial importance since 1860. Harvesting begins in the South in the winter and progresses northward with the advancing season until summer finds them fruiting in the Northern states. There are three main sources of cultivated strawberries, of which there are hundreds of varieties. The native plant of eastern North America, *Fragaria virginiana*, was grown by the early settlers and taken by them to England, where it has been cultivated since the seventeenth century. The European *F. vesca*

is the source of the everbearing types, grown both here and abroad, and often escaping from cultivation. The majority of the cultivated forms, however, are derived from *F. chiloensis*,



FIG. 183.—Plants of the Chesapeake strawberry, a large attractive variety with fine eating qualities. (*Courtesy of the Connecticut Agricultural Experiment Station in New Haven.*)

a native of Western America from Chili northward to the mountains of Mexico. This species is less hardy than the others. Strawberries are a dessert fruit primarily, but are also canned and used in jams and preserves and as a flavoring material. The United States produced 11,681,000 crates in 1935.

CHAPTER XIX

TROPICAL FRUITS

The number of edible tropical fruits is legion. Thousands of them are used daily by the native peoples, and most of these are unknown to the white man. There are 250 edible fruits in the Philippine Islands alone. Sooner or later the people of the United States as well as of other temperate regions will have to turn to a greater extent to the tropics to supplement their own food resources, and fruits are among the best products that the tropics have to offer. Improved methods of transportation will make it possible to use fruits actually grown in the tropics, while Florida and California have a climate favorable to the cultivation of many tropical species. Several tropical fruits have already been exploited. The banana and pineapple are now as familiar as the apple and pear, and citrus fruits are known the world over. In comparison with the fruits of temperate regions, tropical fruits have been much neglected horticulturally and few improvements have been made over the wild product. This condition is now being remedied and with the use of scientific methods of fruit growing the products of the tropics should be all the more valuable. While edible fruits occur in a vast number of families, they are particularly important in the *Anacardiaceae*, *Annonaceae*, *Myrtaceae*, *Rutaceae*, *Sapotaceae*, and *Sapindaceae*. Of these the *Rutaceae* is the best known and most important, for it is the source of the citrus fruits.

CITRUS FRUITS

The citrus fruits were domesticated from wild ancestors in Eastern and Southern Asia in very early time. Some of them have been cultivated for over 3000 years. They were sometimes grown for other purposes than eating. Citron, for example, was planted in the famous Hanging Gardens of Babylon for use in toilet water and pomades. These fruits were early introduced into the Mediterranean region, where they have always been an important crop. Altogether there are about 14 species of *Citrus*, and genera that have been segregated from it.

The citrus fruits are thorny aromatic shrubs or small trees. The leathery evergreen leaves are glandular dotted and, although they appear to be simple, are actually unifoliate-compound leaves with a joint between the leaf blade and stalk. The white or purplish flowers are solitary and often very fragrant. The fruit is a modified berry known as a hesperidium. This type of fruit has a thick leathery rind with numerous oil glands. The flesh is very juicy with many juice sacs. A peculiar feature of these plants is the fact that they do not develop root hairs, and are dependent on mycorrhiza—fungi, which are closely associated with the roots—for the absorption of liquids.

Cultivation of the citrus fruits is on a high scale. They are usually grown at sea level where sufficient moisture is readily available. Any well-drained soil, except an extremely sandy one, can be utilized. The various species differ in their resistance to cold, but in general a temperature ranging from 24° to 120°F. is best. They are propagated chiefly by budding. The species hybridize very readily both in the wild state and in cultivation, and there is a great tendency to form "sports."

The citrus fruits are grown around the world. Although they are tropical plants, most of the commercial groves are in subtropical regions. The fruits ripen throughout the year. Oranges and grapefruit are allowed to ripen on the trees, while lemons and limes are picked green.

The United States leads the world in the production of citrus fruits. Florida and California are the principal states, while Texas, Arizona, and some of the Gulf States grow a small amount. The Mediterranean countries are second, with Spain, Portugal, Italy, and Palestine the most important. The West Indies, where the trees grow in great luxuriance, are of increasing importance. South Africa, Australia, and Japan are also large producers.

Although the citrus-fruit industry has been of commercial importance for only a little over 50 years, it nevertheless has been at times exceedingly profitable. Oranges and grapefruit alone have brought a return of $3,000,000, while the industry as a whole has been a sesquibillion one. The outlook for the future is also very bright, for the European market, particularly in the case of canned products, has scarcely been touched.

Oranges and grapefruit are highly esteemed as table fruits, and, apart from their palatable nature, constitute a valuable addition

to our diet. Like all the citrus fruits they contain considerable amounts of the essential vitamin C, the antiscorbutic vitamin, as well as fruit acids. They are also used for marmalade and various confections. Canned products, particularly in the case of the grapefruit, have been developed in recent years and are of increasing importance. Both the flesh and the juice are preserved in this manner. Often the juice of citrus fruits is more important than the fruit itself and it is extensively used in both alcoholic and nonalcoholic beverages. The rind of nearly all these fruits yields a valuable essential oil.

Oranges

Sweet Orange.—The sweet orange (*Citrus sinensis*) is a native of Southeastern Asia, probably China or Cochin China. It was first cultivated between 1500 and 1000 B.C. It reached India very early in history, and was carried to Europe by the Moors or Portuguese before the fourteenth century. The Spaniards were responsible for its introduction into the New World.

The sweet orange is a small evergreen tree with slender blunt spines, growing upward to 20 ft. in height when in cultivation. The leaves have narrow-winged petioles and the flowers are white and very fragrant. The fruit is nearly round, with an abundant, sweet, solid pulp and spindle-shaped juice sacs. Seeds may be present or absent. This orange is the hardiest member of the genus and can be grown in any warm dry climate where the soil is fertile and well irrigated. At first it was grown from seed, but now the plants are budded or grafted. Several types of sweet oranges have been developed: Spanish oranges, with large coarse-grained fruits; Mediterranean varieties, with fine-grained fruits; blood oranges, with a red pulp, or streaked red and white; and the navel oranges, which are seedless, and characterized by the navel at one end, formed by the protrusion of additional carpels produced inside the flesh. Oranges contain from 5 to 10 per cent sugar, 1 to 2 per cent citric acid, and vitamin C.

Orange growing in the United States began in Florida. In 1894 the output was 4,000,000 oranges. Excessive frosts the following winter almost exterminated the crop and reduced the output in 1895 to 75,000 oranges. In spite of the danger of frost and the more recent ravages of the fruit fly, the industry has persisted and in 1935 16,900,000 boxes were produced. The

Florida orange is medium sized, russet or light yellow in color, thin skinned, and very sweet. It is picked when the skin is green and the yellow color develops later. Gases or chemicals are often used to destroy the chlorophyll and bring out the yellow color more rapidly. California is at present the chief producer of oranges, with a 1935 output of 34,894,000 boxes.

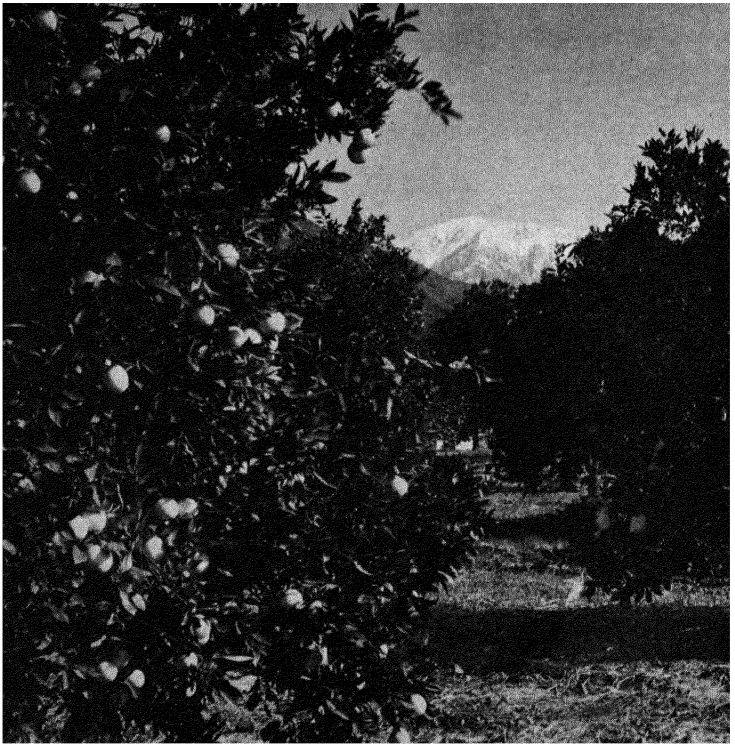


FIG. 184.—A California orange grove. (*Courtesy of the California Fruit Growers Exchange and Ginn and Company.*)

The cultivation of two different varieties make it possible to harvest oranges the year round. The most important of these is the Washington Navel or Bahia orange. This seedless orange originated in Brazil, but in the favorable California climate (Fig. 184) has become the great commercial orange of the world. It is the largest variety, with a thick bright-orange skin, and bears during the winter months. In the summer the

California growers utilize the smaller Valencia orange, a Spanish type with seeds, which is also grown in Florida. Texas, Arizona, Alabama, Louisiana, and Mississippi also grow oranges. The total output in the United States in 1935 was 52,928,000 boxes. The leading foreign countries in sweet-orange production are Spain, Italy, Palestine, South Africa, Brazil, and Japan.

The chief use of sweet oranges is for fresh fruit. Once a luxury, they are now in reach of every purse and are widely used. Orange juice and orangeade are favorite beverages. The peel is candied, and oil of orange is extracted from the rind. This essential oil, which is expressed in Southern Europe and the West Indies, is used in the perfume and soap industries, in medicine, and for flavoring. Orange extract is made by dissolving a small amount of the oil in alcohol. Orange trees are sometimes grown for ornamental purposes.

Sour Orange.—The sour orange (*Citrus Aurantium*), sometimes known as the bitter or Seville orange, is also a native of Southeastern Asia. Curiously enough, it was brought to Spain and cultivated there several thousand years before the sweet orange. It is a small tree, 20 to 30 ft. in height, with blunt spines. The petioles have broad wings. The flowers are exceedingly fragrant and are the source of the oil of neroli, used in perfumery. The large, globose, orange-red fruits are rough and have a very acid pulp. The flesh, however, is of good quality with small spindle-shaped juice sacs. A hollow core develops at the center when the fruit is ripe. The sour orange is grown in the United States for ornamental purposes and to be used as a stock in grafting. It is grown in Spain extensively, however, and the fruits are used for marmalade, orangeade, and candied orange peel. The essential oil obtained from the rind is used in perfumery and in the manufacture of the liqueur curaçao.

King Orange. –The king orange (*Citrus nobilis*) was discovered in Cochin China at the end of the eighteenth century. It was introduced into California in 1880, and is also grown in Florida. It is a small thornless tree with oblate orange or reddish fruits and small leaves. The sweet or slightly acid flesh, with broad, blunt juice sacs, is exceedingly palatable and the peel is very easily removed. The fruit, however, has a poor appearance and has never been very popular. Two varieties

of the king orange are much more important. The so-called glove oranges, the orange-yellow mandarins, and the reddish-orange tangerines comprise var. *deliciosa*. These are small round fruits with an easily removable peel and segments that separate readily. They are grown in Japan and China, Southern Europe, and the Gulf States. The Satsuma orange (var. *unshiu*) is a small, very hardy type with a deep-orange skin and

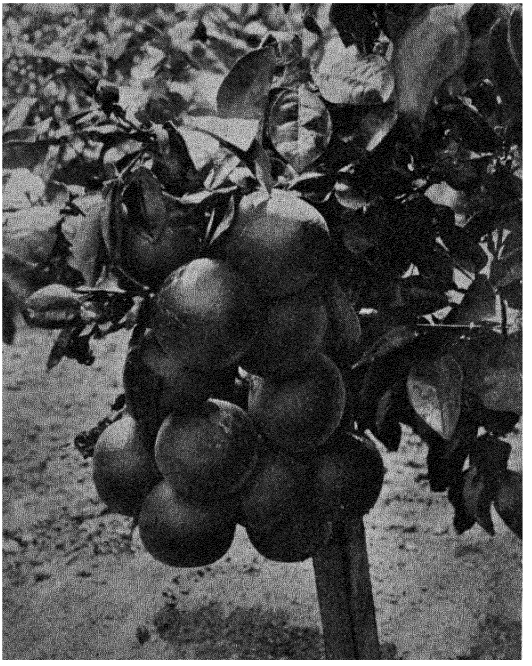


FIG. 185.—A cluster of grapefruit (*Citrus maxima* var. *uvacarpa*). (*Reproduced by permission from Smith and Walker, Geography of Texas, Ginn and Company.*)

pulp, which is grown in Florida and the Gulf States. The fruit is edible before the color develops, so they are often picked when still green in color and gases are used to hasten the formation of the pigment.

Grapefruit

The grapefruit or pomelo (*Citrus maxima* var. *uvacarpa*) originated somewhere in China, Malaya, or Polynesia as a sport of the shaddock. No important fruit has a more doubtful

origin. Many authorities consider it to be merely a horticultural form of the shaddock; others believe it to be a distinct species (*C. paradisi*). It is a vigorous tree, 20 to 40 ft. in height, with winged petioles. The round or pear-shaped, pale-yellow, smooth fruits are produced in clusters (Fig. 185). They are the largest of the edible citrus fruits, weighing from 2 to 12 lb. and with a diameter of 4 to 6 in. The skin is thin with many inconspicuous oil glands. The flesh is acid or subacid and mildly bitter, with large spindle-shaped juice sacs.

The grapefruit was brought to Florida from the West Indies in 1809 and was used as an ornamental tree until 1880. The production of grapefruit has increased enormously since 1905. In 1935 the United States produced 17,945,000 boxes. Of these 10,500,000 boxes were grown in Florida, 2,275,000 in California, and the remainder in Texas and Arizona. Although grapefruit was first canned only in 1917, in 1934–1935 the pack in Florida alone amounted to 3,588,042 cases of "hearts" and 2,236,726 cases of juice. The waste rind and seeds are fed to cattle. Puerto Rico also cans a considerable amount. Grapefruit is grown in the West Indies, India, and South Africa to some extent.

Lemon

The lemon (*Citrus Limonia*) is a native of Southeastern Asia and has been grown there for ages. It must have reached India at an early date for there is a Sanskrit word for it. It has been grown in the Mediterranean region since the days of the Greeks and Romans, and has always been particularly well adapted to that area, growing everywhere in moist fertile soil. The lemon is a small tree, 10 to 20 ft. in height, with short spines and large white and purple flowers. The small, light-yellow, oval fruits end in a blunt point. The fruit is picked green, as it deteriorates if allowed to ripen on the tree. Regardless of the state of maturity, it is removed when about 2¼ in. in diameter. It is then cured, and colored and ripened in storage. Lemons contain 0.5 per cent sugar and 5 per cent citric acid. The juice is used for lemonade and other beverages and as a flavoring material, bleaching agent, and stain remover. Although widely grown, commercial production is restricted to warm regions, for it is not very hardy. Italy produces two-thirds of the world crop of

20,000,000 boxes. California is second with a production in 1935 of 8,500,000 boxes. Lemons were formerly grown in Florida, but the trees were too often injured by frost to be of commercial importance. The rind is the source of oil of lemon. The expression of the oil is an important industry in Sicily, where the sponge method is used. It takes from 800 to 1100 lemons to yield 1 lb. of the oil. Lemon oil is used in perfumery and soap and lemon extract, which is next to vanilla in importance as a flavoring substance. The extract is made by dissolving 5 parts of the oil in 95 parts of strong alcohol. The utilization of cull lemons has recently been developed in California with a large production of citric acid, lemon oil, and pectin.

Lime

The lime (*Citrus aurantifolia*) was likewise domesticated in Southeastern Asia. It is very susceptible to cold and is a distinctly tropical plant. It is a low straggling shrub or small tree with numerous very sharp spines and small white flowers. The fruits are small, from 1¼ to 2½ in. in diameter, and are greenish yellow in color. They are thin skinned, with an abundant acid pulp and oval pointed juice sacs. The lime is one of the sourest fruits on the market and is not suitable for eating. It is grown chiefly for the juice, which is often extracted and shipped in a raw or concentrated form. Lime juice is used in beverages, as a source of citric acid, and medicinally to prevent scurvy. Although long famous for the latter purpose, lime juice actually contains only one-quarter as much vitamin C as either oranges or grapefruit. Limes are grown throughout the tropics, but are of commercial importance only in Italy, the West Indies, and Florida, where 10,000 boxes were produced in 1935. Oil of lime is expressed from the rind.

Kumquat

The kumquats are the smallest of the citrus fruits. They are small evergreen shrubs with aromatic white flowers and golden-yellow fruits produced in clusters. The fruits are from 1 to 1¼ in. in diameter with a thick spicy rind, acid flesh, and small seeds. They are grown for ornamental purposes and for eating, either whole or preserved. They are usually placed in the genus *Fortunella*, a segregate of *Citrus*. Three oriental species are

grown to some extent in the orange belt. These include *F. japonica* with globose fruits, *F. margarita* with oval fruits, and *F. crassifolia* with a sweet rind and juiceless pulp.

Citron

The true citron (*Citrus Medica*) is the oldest of the citrus fruits, going back as far as the fourth century B.C. It originated in northern India and has long been cultivated in Southeastern Asia. It was described by Theophrastus from Babylon. The citron is a small thorny tree with attractive purple and white flowers and a fruit resembling a large lemon. It is fragrant, greenish yellow in color, oblong in shape, and from 6 to 9 in. in length. The thick skin is tough and warty and the acid pulp is scanty. Commercial citron is the candied rind. It is prepared by treating the fruit with brine to remove the bitter oil. This also brings out the flavor and aroma and prevents decay. Then the rind is candied in a sugar and glucose solution. Citron is one of the best and most expensive of the condiments. About 6000 tons are produced annually, of which the United States uses half. Citron is cultivated chiefly in Corsica, Sicily, Greece, and the West Indies. The essential oil of cedrat used in perfumery is expressed from the rind.

Citrus Fruits of Minor Importance

The **bergamot** (*Citrus Bergamia*) is a small spiny tree with golden-yellow pear-shaped fruit. The pulp is very acid and inedible. The plant is grown in the Mediterranean region as a source of the oil of bergamot, which has already been discussed under essential oils.

The **calamondin** or Panama orange (*Citrus mitis*) is a native of the Philippine Islands. It is a small thick-topped tree with bright-green leaves and a few short prickles. The small fruits, which resemble tangerines, are produced on the tips of the branches. They have a loose skin and a well-flavored acid pulp. The calamondin is one of the hardiest of the citrus fruits and has recently been introduced into this country. It is used for beverages.

The **shaddock** or pomelo (*Citrus maxima*) is a native of Malaya and Polynesia. Several kinds are grown in Southern Asia. The fruit is like a grapefruit, but much larger, growing

to the size of a watermelon and weighing 10 to 20 lb. It is more pear-shaped, with larger juice sacs and a hollow core, and has a coarse thick rind and thick leathery septa. The reddish flesh is aromatic and spicy, but quite bitter. This species was introduced into the West Indies by a Captain Shaddock, for whom it has been named. The shaddock has given rise to the grapefruit.

The **deciduous orange** (*Poncirus trifoliata*) is a native of China and Japan. It is a low tree with large spines and trifoliate deciduous leaves. For this reason it has been segregated from *Citrus*. The white flowers are produced before the leaves. The rough hairy orange fruits have a bitter, gummy, inedible pulp. This species is very hardy and is used in hybrids and as a stock for grafting the other citrus fruits. It is cultivated as an ornamental plant as far north as New York.

In an attempt to develop edible citrus fruits that are hardier than oranges, many **hybrids** have been produced. Some of these, like the citrange, a hybrid between the trifoliate and the sweet orange, are grown to a considerable extent in the Southern states. Others include the tangelo (tangerine × grapefruit), limequat (kumquat × lime), orangequat (kumquat × orange), citrangequat (citrange × kumquat), tangerona, and orangelo.

OTHER TROPICAL FRUITS

Banana

The banana (*Musa paradisiaca* subsp. *sapientum*) is one of the most familiar and important of all tropical fruits. From its original home in India or Malaya it has spread all over the tropical world, and today there is almost no warm region where it is not grown, except the Sahara Desert, which is too arid. It is likewise a very ancient plant. We know it was important in Assyria in 1100 B.C., and it was well-known to all the other early civilizations. It reached Polynesia, also, at a very early date and was carried to the West Indies in 1500 A.D.

The banana is one of the tallest of the herbaceous plants. Its robust treelike stem is composed of the sheathing spiral leaf bases, which contain fibers of sufficient strength to make possible the erect habit. At the summit of the 10- to 20-ft. stem there is produced a crown of large oval deep-green leaves.

These are about 4 ft. in length and 1 ft. in width, with a prominent midrib.

Each plant produces a single inflorescence. This consists of clustered flowers which are nearly surrounded by large, fleshy, reddish, spathelike scales, which drop off as the fruits mature. The flower stalk develops from the rootstalk and pushes its way



FIG. 186.—Transporting bunches of green bananas (*Musa paradisiaca* subsp. *sapientum*) from a plantation to a railroad. (*Courtesy of the United Fruit Company.*)

up through the hollow stem, emerging in the center of the crown. It soon curves over owing to its own weight.

These drooping inflorescences develop into the familiar "bunches" of bananas. Marketable bunches (Fig. 186) weigh from 80 to 100 lb., and consist of from six to nine clusters, known as "hands" or "combs." Normally each hand contains from 10 to 20 individual bananas, or "fingers." Bunches with as many as 22 hands and 300 individual bananas have been produced, but these are unusual. The fruit of the cultivated banana is a modified berry and lacks seeds. Wild species occur, however, which produce normal seeds. As soon as the tree bears, it dies

down, or is cut down, and suckers develop from the rhizome, which give rise to new plants (Fig. 187). A single clump may be productive for several years. Bananas are rapid growers and have a very high yield. This varies with the locality and may be as low as 125 or as high as 300 to 400 bunches to the



FIG. 187.—A plantation of bananas (*Musa paradisiaca* subsp. *sapientum*) in Costa Rica, showing vegetative reproduction. The plants are nine months old. (*Courtesy of the United Fruit Company.*)

acre. It has been estimated that a unit area of land produces 33 lb. of wheat, 98 lb. of potatoes, and 4400 lb. of bananas.

In the various tropics about 300 varieties of bananas are grown. Only a few of these reach the markets of the United States. Tropical American markets have about 15 kinds, but the vast majority are grown in tropical Asia. There are other species of bananas as well, one of which, the dwarf banana (*Musa nana*),

is occasionally seen in our markets. Red bananas are quite common.

Bananas are picked and shipped green. When thoroughly ripe, as indicated by brown blotches on the yellow skin, they constitute an excellent food. They have a high content of carbohydrates with some fats and proteins as well. In fact, their food value is three times that of wheat. Bananas are usually eaten raw, but may be cooked.

The **plantain** (*Musa paradisiaca*), a close relative of the banana, is one of the great food plants of the tropics. A native of Southern Asia, it has furnished food for all tropical peoples for centuries. There are some 75 varieties, all so old that they have never been propagated by seed within recorded time. Plantains are always eaten cooked or made into flour. They are very digestible and are a valuable food for children and invalids.

Custard Apples

The term "custard apple" is rather loosely applied to several fruits of the American tropics belonging to the genus *Annona*. In all these the fruit is a fleshy syncarp, formed by the fusion of numerous ripened ovaries and the receptacle.

The **cherimoya** (*Annona Cherimolia*) is highly esteemed as a dessert fruit. It is very old and originated in the Andes of Peru and Ecuador. It is now grown in Central America, Mexico, the West Indies, Africa, and India. The cherimoya is a shrub or small tree with fragrant flowers The light-green fruits are globular or conical and from 4 to 10 in. long. The luscious white or yellowish flesh is very aromatic and fragrant, with a soft and custardlike consistency.

The **sweetsop** or sugar apple (*Annona squamosa*) is a native of South America and the West Indies, and is now widely grown in the tropics of both hemispheres. The yellowish-green tuberculate fruit is about 2 or 3 in. in diameter. It has a white custardlike pulp and is the best of the group for eating.

The **soursop** (*Annona muricata*) of the West Indies is a small slender tree with a large ovoid spiny fruit, deep green in color. The fruit may be 8 in. in length and weigh as much as 5 lb. The white juicy flesh is very aromatic. The soursop is unrivaled for sherbets and drinks.

The **custard apple** or bullock's-heart (*Annona reticulata*) is a common tropical fruit. The fruit itself (Fig. 188) is heart-shaped, 4 to 6 in. in length, and brownish or reddish in color. The white pulp is slightly granular toward the rind and rather insipid and cloying. It is a native of the West Indies.

The family *Annonaceae* contains about 600 species, most of which have edible fruits, and affords great promise for future development.

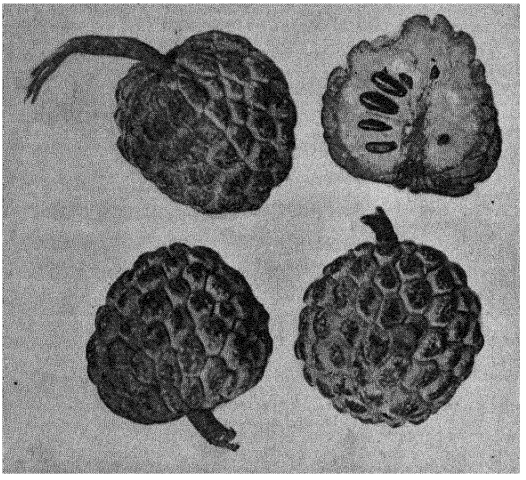


FIG. 188.—Fruits of the custard apple or bullock's-heart (*Annona reticulata*).

Date

The date (*Phoenix dactylifera*) is one of the oldest of crops, going back at least 5000 years. It probably is a native of India or Arabia, but has long been domesticated throughout Southwestern Asia and Northern Africa. It was in Arabia before the dawn of history, was of great importance in Babylonia, and had reached Egypt long before the Christian era.

The date (Fig. 189) is a palm with a slender trunk, 70 to 100 ft. or more in length. It tends to produce offshoots from the base, and so is often found growing in clumps. It has a crown of stiff, pinnate, ascending and descending leaves 10 to 20 ft. in length. The numerous flowers, sometimes 10,000 to an inflorescence, are

surrounded by a spathe. Male and female flowers are produced on different trees, and in cultivation 90 per cent of the male trees are removed. The fruit, a nearly round drupe, or one-seeded berry, is hard and green at first, but later turns yellow or red. The flesh is thick and very sweet, and is soft or dry and hard, depending on the variety. The date can grow with less water than any

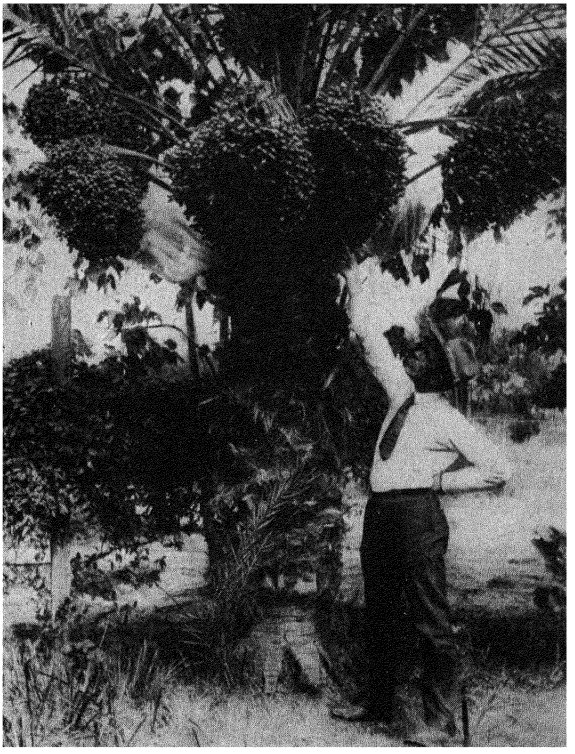


FIG. 189.—A date palm (*Phoenix dactylifera*) in fruit. (*Courtesy of S. J. Record.*)

other crop, and so is of the utmost importance to desert peoples. If often serves as a staple food, as well as the main source of fruits and sugar. It is distinctly a plant of hot sunny climates with low humidity. In exceedingly arid areas some irrigation is necessary. A favorite habitat is the oasis. Dates are propagated by seeds or cuttings. They are very long-lived, often reaching an age of 200 years. Over 1000 varieties are grown. The fruits are ripened off the tree and are dried before shipping. Unlike most

fruits they have a high food value, with 54 per cent sugar and 7 per cent protein as well as pectins and gums.

Dates are used as a table fruit and in jams, pastes, cooking, and alcoholic beverages. In desert regions it has been estimated that the articles that are made from the date palm and the uses to which it is put number more than 800. Every part of the plant is utilized, and the fruits even serve as money.

Iraq, the site of ancient Mesopotamia, produces 80 per cent of the dates of commerce and has 20,000,000 trees under cultivation. Arabia and Northern Africa are also large producers. Dates have been grown in California since the eighteenth century, but have been commercially important only since 1890. As a result of scientific study we now know more about the date and its requirements than about any other tropical crop. In 1935 about 6,506,000 lb. were produced in California and Arizona. Dates are also grown in Mexico.

Durian

The durian (*Durio zibethinus*) is one of the most interesting of all tropical fruits. It is a native of Malaya, and occurs locally in that region, and to some extent in Burma and the East Indies. It is rarely cultivated. It is a tall handsome tree, up to 80 ft. in height, with large conical spiny fruits, 6 to 8 in. in diameter. The leaves are densely covered with golden hairs on the underside. The flowers are yellow or creamy white. The custardlike flesh has an exquisite flavor and is at the same time aromatic and sweet with a strange balsamic taste. The odor, however, is extremely offensive and is a serious obstacle to the popularity of the fruit. Durians are much sought after by the native people, and by animals as well. It has been claimed that the fruit possesses great rejuvenating powers.

Fig

The fig (*Ficus Carica*) has been cultivated since earliest time. It originated in southern Arabia and early spread to the Mediterranean region. It is frequently mentioned in the Bible. Theophrastus was familiar with many varieties and in his "Inquiry into Plants" gives a detailed account of fig cultivation. Today figs are grown in nearly all tropical and subtropical countries. The fig (Fig. 190) is a shrub, or small tree, with character-

istically lobed leaves. The fruit is a synconium, a fleshy hollow receptacle with a narrow aperture at the tip. The true fruits, which are small achenes, are borne on short stalks on the inside of the synconium.

Several different types of figs occur: common figs, caprifigs, Smyrna figs, and San Pedro figs.

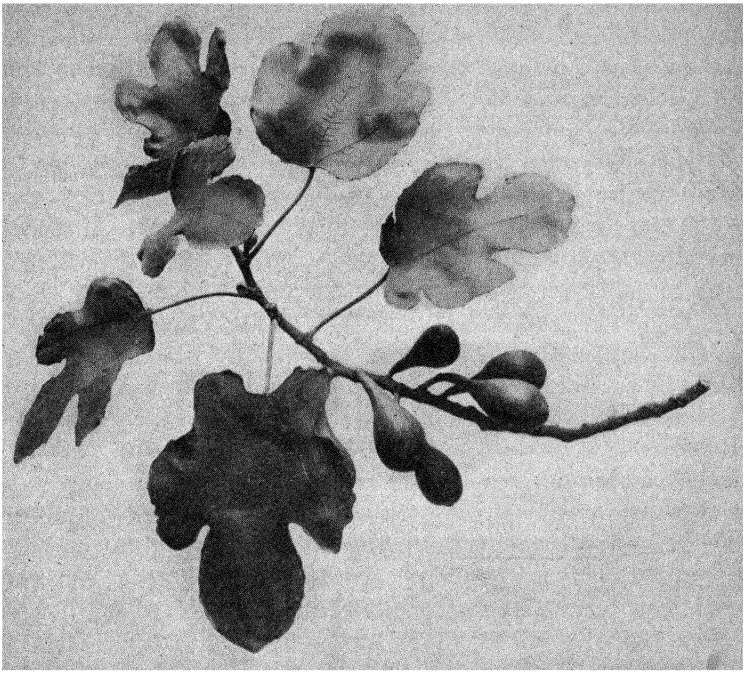


FIG. 190.—Glass model of the leaves and fruit of the fig (*Ficus Carica*). (*Courtesy of the Botanical Museum of Harvard University.*)

In the **common figs** the fruits develop without pollination and have no seeds. Two crops are produced annually. The first crop (brebas) are larger and more juicy and are usually eaten fresh. They are borne on the old wood. The second crop is produced in the axils of the leaves. They are used fresh or are dried. Between 600 and 800 kinds of common figs are known. They are usually propagated by cuttings.

The **caprifigs** are wild figs that grow naturally in the Mediterranean region and Western Asia. Although of no commercial

value as fruit, they are cultivated in most fig-raising countries, for they are essential to the development of the Smyrna fig. The life history of the caprifig is closely connected with that of a small wasp (*Blastophaga grossorum*), which brings about cross pollination. Caprifigs produce three crops of fruit a year. The spring crop (profichi) contains staminate flowers and the so-called gall-flowers. These are similar to pistillate flowers but have short-styled ovaries. The fig wasp enters the young figs and lays eggs in the gallflowers. In about two months the new generation of wasps hatches out and emerges from the fig, becoming covered with pollen in so doing. By this time the summer crop of figs (mammoni) have been produced, which contain chiefly gall-flowers. The wasps enter these and deposit eggs in most of them. Although these are pollinated by the wasp, the presence of the larvae inhibits seed development. Any flowers in which eggs were not placed are able to develop fertile seed. There is often a continual crop of these summer figs until cold weather sets in, and figs and wasps can be found in all stages of development Late in the season the winter crop (mamme) of figs is developed and after visitation by the wasps remains on the tree over winter. The larvae mature in April, when a new crop of profichi figs is ready to receive the wasps, and the annual cycle is resumed.

In **Smyrna figs** no staminate flowers are produced, and consequently these figs are absolutely dependent on cross pollination from caprifigs. This process is known as caprification and is brought about artificially. Branches of caprifigs of the profichi crop are suspended on the Smyrna tree. The wasps, on emerging, enter the partly developed Smyrna figs and effect pollination. Unlike the caprifigs, the ovaries have styles so long that the wasp is unable to deposit eggs in the proper place, so the ovules are able to develop normally after fertilization. The wasps, thwarted in their attempt to raise another generation, emerge from the fig or die within the cavity. Smyrna figs have a superior nutty flavor due to the presence of the fertile seeds. They are the most important commercial fig, and are extensively grown in Asia Minor, Greece, Algeria, and parts of Portugal and California. The early attempts at cultivation in California and elsewhere met with continued failure until the profichi crop of caprifigs and the fig wasp were introduced.

The **San Pedro figs,** which are grown to some extent in California, have two crops annually. The first develops without pollination, while the second fails to mature and falls from the tree, unless it is caprified.

Figs are used fresh, dried, preserved, or canned. A considerable amount is used in baking, and ground up for fig coffee. In addition to their food value, they have definite laxative properties and are of importance in medicine.

In 1935 the United States produced 35,590 tons in California and Texas, and also imported a considerable amount, chiefly from Turkey, Greece, and Italy.

Granadilla

The granadillas are the edible fruits of various species of passion flower. These are woody tendril-bearing vines with solitary showy flowers and a many-seeded berry. They are natives of tropical America.

The purple granadilla (*Passiflora edulis*) is a native of Brazil, but is cultivated all over the world. In Australia it is of considerable economic importance. It is also grown in Ceylon, the Mediterranean area, and the southern United States. The flowers are white, with a white and purple crown. The deep-purple fruit, about 3 in. in length, is used as a table fruit and in sherbets, candy, and beverages.

Other common species include the giant granadilla (*Passiflora quadrangularis*), with greenish-yellow fruits reaching 10 in. in length; and the sweet granadilla (*Passiflora ligularis*).

Guava

The guava (*Psidium Guajava*) is another tropical American fruit that has been cultivated for centuries. It was known to the Incas, and had spread all over tropical America before the time of the early navigators. Today it is common in the tropics everywhere and is of increasing importance in Florida and California. The plant is a shrub or small tree with large white flowers. The yellow berrylike fruit is about 4 in. long and has a variously colored flesh. The guava is a very aromatic, sweet, juicy, and highly flavored fruit with a fine balance between the content of acid, sugar, and pectin. It is usually used for jellies, preserves, and pastes, but is equally good as a fresh fruit.

The family *Myrtaceae*, to which the guava belongs, probably has more different species with edible fruit than any other family. In addition to the guavas, of which there are about 150 species, there are the eugenias with nearly 700 species. Some of these are of considerable importance. The rose apple (*Eugenia Jambos*) of tropical Asia is now being grown in Florida for its greenish-

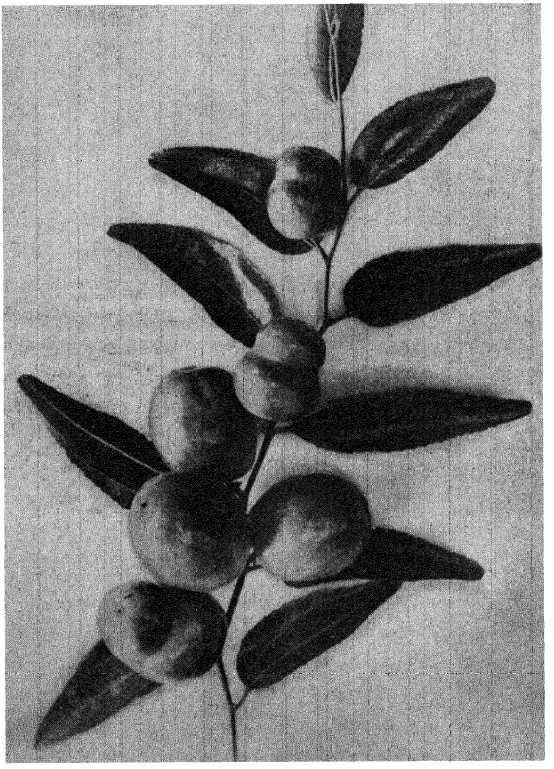


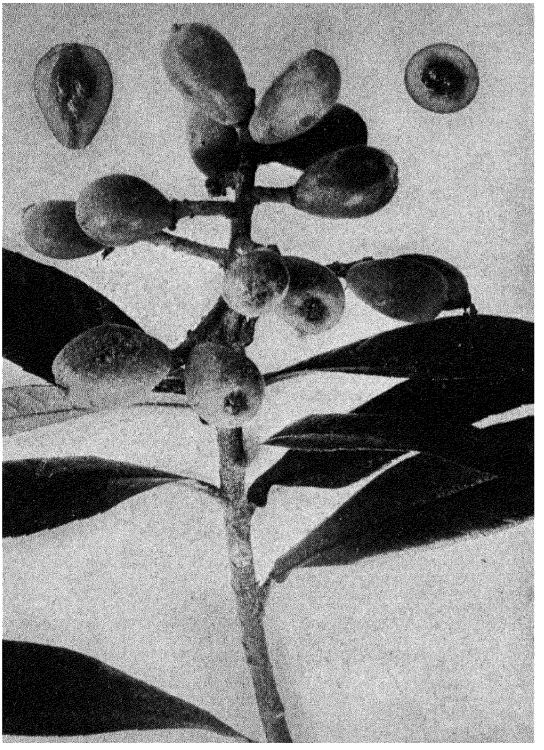
FIG. 191.—A fruiting branch of the jujube (*Zizyphus Jujuba*).

yellow fruits, which are used in preserves and candy. The pitanga (*E. uniflora*), considered to be the best of the genus, is grown in Florida and California for use as a fresh fruit and in jellies and sherbets. Other related species of note include the feijoa (*Feijoa Sellowiana*) and the jaboticaba (*Eugenia cauliflora*).

Jujube

The jujube (*Zizyphus Jujuba*) is a native of China, and has been cultivated in that country for at least 4000 years. It is still

one of the five chief fruits of China, and is also grown elsewhere in Southeastern Asia and in New Zealand. It can be grown in all tropical and subtropical countries, and since 1900 has been grown to an increasing extent in California, Texas, and Mexico. It promises well as a fruit tree for the Southwestern states as it is



remarkably free from pests. The jujube is a large bush or small spiny tree with a small dark-brown fleshy drupe (Fig. 191), which has a white, crisp, rich flesh. It is used fresh, dried, or preserved, and is useful in cooking and candymaking.

Litchi

The litchi (*Litchi chinensis*), a native of Cochin China and Siam, has been an important fruit in Southeastern Asia for over 2000 years. It is now widely grown in the tropics, and has been introduced into California and southern Florida. The tree is valuable

for ornamental purposes. It reaches a height of 35 or 40 ft. and has a broad round-topped crown and leathery shiny leaves. The fruits are very distinctive. They are round, 1 or 2 in. in diameter, and are borne in loose clusters. The pericarp is bright red and leathery, becoming brown and brittle on drying. The translucent white flesh surrounds a single large seed. In the dried fruit, the litchi "nuts" of the Chinese restaurants, the flesh has a raisinlike consistency. The fresh fruit is a great delicacy in China. In Kwantung alone 30,000,000 lb. are produced. Litchis are canned for the export trade.

Loquat

The loquat (*Eriobotrya japonica*) is one of the few tropical fruits belonging to the *Rosaceae*, a family which furnishes such a large number of edible fruits in temperate regions. It is a native of China, but is now grown in most tropical and subtropical regions. It has been introduced into California, Florida, and the Gulf States. The loquat is a small evergreen tree with broad leaves and fragrant white flowers, which appear in the fall. The small, round, downy, yellow-orange fruits (Fig. 192) are produced in the spring. The flesh is slightly acid and not so sweet and rich as most tropical fruits. It is highly esteemed in the Orient and has been grown since antiquity. Japan produces 20,000,000 lb. The fruit is used fresh, and is made into jellies, pies, and sauces.

Mango

The mango (*Mangifera indica*) is one of the oldest and most important of tropical fruits. It has been cultivated for nearly 6000 years. Few fruits have the same historical background or are so closely connected with folklore and religion. It is a sacred tree in India. A native of Southern Asia, it is now grown in Malaya, Polynesia, Africa, and tropical America, including southern Florida and California. The mango is one of the few tropical plants that have been improved under cultivation, and upward of 500 horticultural varieties are now grown. The tree is a beautiful evergreen, growing to 90 ft. in height, with small pink flowers in large panicles. The fruit (Fig. 193) is a fleshy drupe with a thick yellowish-red skin and a large seed. The size, shape, and quality of the mango vary greatly. The length is from 3 to 5 in. The pulp is orange, yellow, or red in

color, and when ripe has a rich, luscious, aromatic flavor with a perfect blending of sweetness and acidity. Young and inferior fruits are often fibrous and unpleasantly acid and sometimes prejudice the consumer against all mangos.

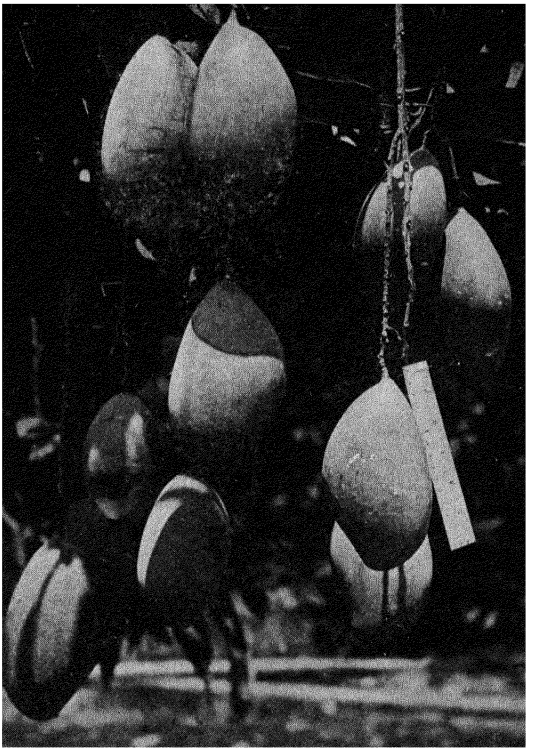


FIG. 193.—Mango fruits. The mango (*Mangifera indica*) is one of the oldest and most important of tropical fruits. (*Reproduced from the National Geographic Magazine, October*, 1911.)

Mangos occupy a more important position among tropical fruits than apples among temperate fruits, and they furnish food for at least one-fifth of the world's inhabitants. Ninety-nine per cent of them are eaten fresh. They are used in preserves, salads, and sauces, such as chutney. They are also cooked, dried, and canned. The total production is estimated to be over 100,000 tons.

Mangosteen

The mangosteen (*Garcinia Mangostana*) is generally considered to be the world's best flavored fruit, and is highly prized in regions where it can be grown. It is a native of the Malayan region and is common in the East Indies, Cochin China, and Ceylon. A few plants have been introduced into the West Indies, but the fruit is as yet unavailable in America. The

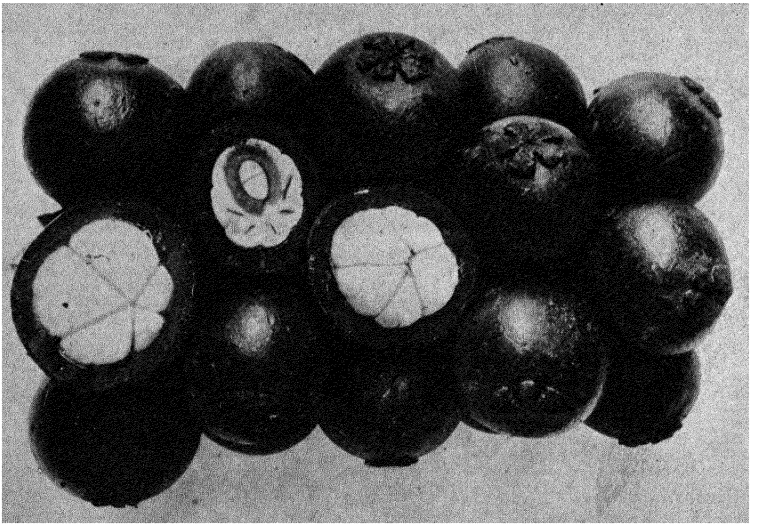


FIG. 194.—Fruits of the mangosteen (*Garcinia Mangostana*) tied in preparation for street vending in Java. Several fruits were cut later to show the contents. (*Photo by Oakes Ames*)

tree is small, rarely over 30 ft. in height, with deep-green foliage. The fruit (Fig. 194) is a dark-purple berry, 2 or 3 in. in length, with adherent sepals at the base. The rind is ½ in. in thickness and the flesh is so delicate that it melts in the mouth like ice cream. The pulp is white or yellowish, with crimson veins, and exudes a yellow juice of an exquisite flavor.

There are over 200 species of *Garcinia*, two-thirds of which have edible fruit, and many of these are being grown experimentally in this country. The mamey or mammee apple (*Mammea americana*), a close relative of the garcinias, is an

important edible fruit in the West Indies and tropical America and should be cultivated in the Old World.

Olive

The olive (*Olea europaea*) is one of the oldest of fruits and has been grown from prehistoric time. It was known in Egypt in the seventeenth century B.C. and is frequently mentioned in the Bible and in Greek and Roman writings. At the present

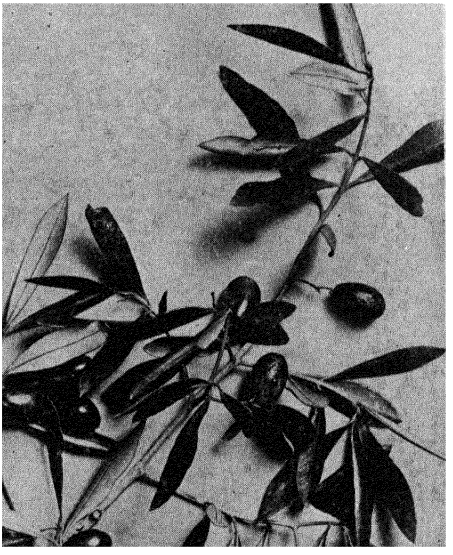


FIG. 195.—Leaves and fruit of the olive (*Olea europaea*). (*Courtesy of the Arnold Arboretum.*)

time it is cultivated everywhere in the Mediterranean region and has been widely introduced throughout the tropics and subtropics. It has been grown in California since 1769 for ornamental purposes. The fruit has been of importance commercially in that state since 1890.

The tree is a small evergreen 25 to 40 ft. in height with leathery entire leaves. It bears whitish flowers and a one-seeded drupe (Fig. 195). The fruit is a shiny purplish black when ripe. Although living to a great age under favorable conditions, olives require careful cultivation. A deep fertile soil and a temperature averaging 57°F., and never going below 14°F.,

are desirable. Irrigation is often necessary. The tree is propagated by cuttings.

Ripe olives have a high food content for they are one of the few fruits rich in oil. They are cultivated for eating, but more especially as a source of olive oil, which has already been dis-

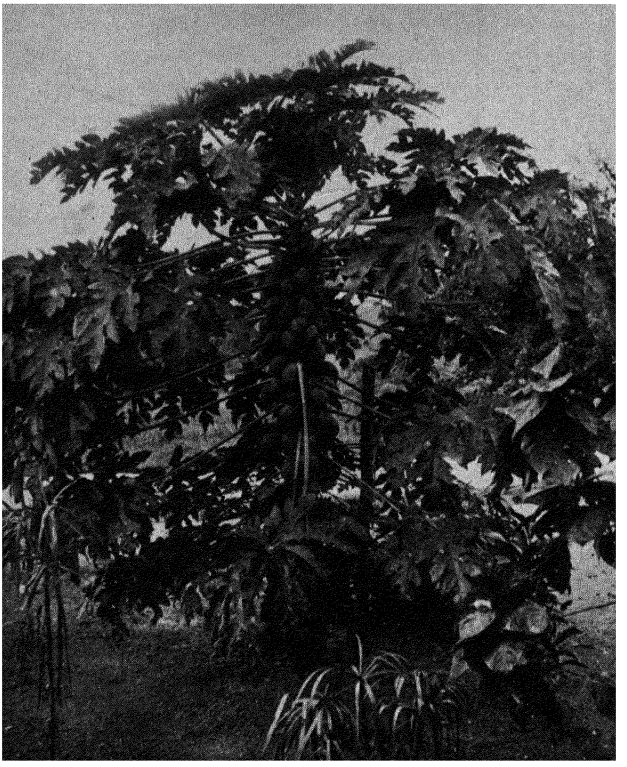


FIG. 196.—A papaya tree (*Carica Papaya*) in fruit in Florida.

cussed. Green olives are also a favorite food. These are picked by hand when fully grown, but still unripe. They are cleaned, heated with lye, which softens them and removes the bitter principle that is present, and pickled in brine. Stuffed olives, with the stone removed and replaced by a pimiento or nut, are a familiar product. The United States grew 56,000,000 lb. of olives in 1935, and imported large quantities as well. Spain, Italy, and Greece are the chief exporting countries.

Papaya

The papaya or papaw (*Carica Papaya*), a native of tropical America, is now widely dispersed. It is a valuable food and drug plant in the West Indies and Ceylon, and is also grown in India, Malaya, California and Florida, and the Hawaiian Islands, where it is of great importance. The papaya tree, which is really a giant herb 25 ft. in height, is dioecious. The straight stem is rather succulent, with a crown of large, deeply seven-lobed leaves and yellow flowers. The fruits are fleshy berries, resembling melons in appearance. They are yellow-orange in color, weigh up to 20 lb., and are borne on long stalks just below the crown of leaves (Fig. 196). The papaya is an excellent breakfast fruit, the orange flesh having a sweet musky taste. It is also used for salads, pies, sherbets, and confections. Unripe fruits are cooked or preserved. The fruit and other parts of the plant contain a latex that is used in chewing-gum manufacturing. One of the constituents of the latex is a digestive ferment, papain, which acts on proteins in a manner similar to pepsin. This ferment is important in medicine. Considerable papaya is imported, chiefly from Ceylon.

This true papaya should not be confused with the *papaw* (*Asimina triloba*) of temperate North America. This deciduous tree, with drooping leaves, axillary purple flowers that appear before the leaves, and edible fruits, grows from New York to Florida and Texas.

Persimmon

The **Japanese persimmon** or kaki (*Diospyros Kaki*) is a native of China and has spread from there around the world. Over 800 varieties are grown in Japan. It is cultivated in France and other Mediterranean countries, and is common in California, Texas, Florida, and the Gulf States. It is a large tree, 40 ft. or more in height, with orange-red fruits 3 in. in diameter. These are edible berries, with an enlarged calyx at the base. They are eaten fresh or dried.

The **native persimmon** (*Diospyros virginiana*) of the eastern United States is a hardier and smaller temperate relative. The ripe fruits are of high quality and delicious flavor and should be more widely used. The unripe fruits, which often reach our

markets, are, however, very acid, while ripe fruits are somewhat pulpy and are hard to transport. These characteristics have tended to offset the more favorable features, and the Japanese persimmon is more popular.

Pineapple

The pineapple (*Ananas comosus*) is one of the few tropical fruits that has been exploited commercially, and it is known the



FIG. 197.—A field of pineapples (*Ananas comosus*) in Florida.

world over. No other tropical crop except rubber has had a more rapid rise in international trade, owing to good luck and good management, as well as to its own intrinsic qualities.

The pineapple is a native of northern South America. It had reached the West Indies before the coming of the white man and the native Indians were growing it everywhere. Wild forms are still found in Brazil. The ananas, as they were called, were carried by the Spaniards and Portuguese to the Old World, and spread all over tropical Asia, Africa, the East Indies, and Polynesia.

The plant (Fig. 197) is a perennial herb, with a short stem and rosette of stiff leaves, 3 ft. in length, with spiny tips and prickly margins. The flowers are borne in dense heads and are crowned by a tuft of leaves. The large fruits, which weigh from 1 to 32 lb., are syncarps. These are multiple accessory fruits formed from the whole inflorescence. The individual ripened ovaries are embedded in a fleshy mass formed from the bracts, sepals, petals, and axis of the inflorescence. The pineapple is a very dependable crop. The plants are propagated by suckers, cuttings, and occasionally from seed. They can be grown in a poor dry sandy soil. Several varieties are known.

There are few larger, better flavored, or more wholesome fruits in the market. In addition to the content of sugar and fruit acids, a valuable digestive ferment, bromelin, is present. Pineapples must be left on the plant until fully ripe in order for the full flavor to develop. Most of the fruits that are available outside the regions where they are grown are picked before maturity, so that the majority of people have never experienced the delicious flavor of a fully ripe "pine." Since 1900 pineapples have been canned and today the canning industry is very important. It has been estimated that the total annual output is 190,000,000 cans, with a value of over $30,000,000. Machines have been developed which do all the work in a very few seconds. The waste products are all utilized in one way or another. Pineapple juice, which is used in beverages or alone, is also canned extensively.

Although grown everywhere in the tropics, the chief commercial area lies outside the true tropics. Hawaii leads in production, with 75 per cent of the world's crop, most of which is canned. Cuba, Puerto Rico, and Central America supply the United States with most of its fresh fruit. At one time Florida was important, but at present pineapple growing is of only local interest. Borneo and the Malay States are large producers, and grow some very fine types.

Piña fiber, which is obtained from the leaves, has already been discussed.

Pomegranate

The pomegranate (*Punica Granatum*) is a native of Persia. It has been cultivated for centuries and early spread to the

Mediterranean region and Southern Asia. It was grown in the famous Hanging Gardens of Babylon. It is a bush or low tree with orange-red flowers. The round berrylike brownish-yellow or reddish fruits are 2 to 4 in. in diameter and are crowned with the thick persistent calyx. They have a hard rind, an edible pulp with amethyst-colored juice and many seeds (Fig. 198). Pomegranates are a very refreshing fruit and are used as a table or salad fruit and in beverages. The roots, rind, and seeds are

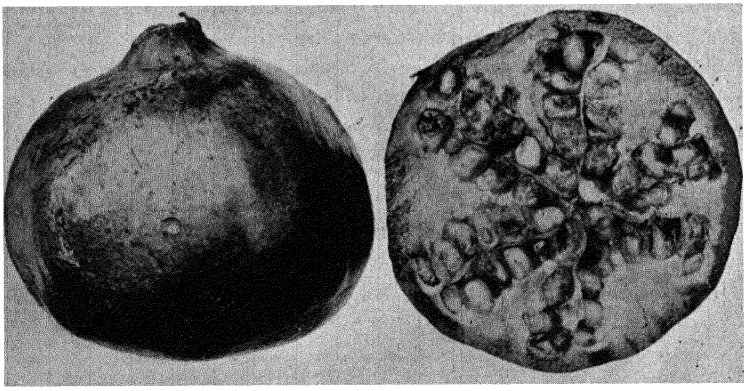


FIG. 198.—The fruit of the pomegranate (*Punica Granatum*), showing the whole fruit and a transverse section.

medicinal. Pomegranates have been widely introduced in arid tropical and subtropical regions, and are grown in southern California, Arizona, and New Mexico.

Sapodilla

The sapodilla (*Achras Zapota*) is one of the best fruits of tropical America. The tree is a stately evergreen, 75 ft. in height, with a dense crown and horizontal branches. It has white flowers and a large rough brown fruit 3 to 4 in. in diameter. The yellowish-brown flesh is translucent and very sweet and wholesome. Young fruits contain considerable tannin and are unpalatable. The tree is now grown in Florida and in the tropics and subtropics of the Old World. The chief commercial product of the tree, however, is not the fruit but the milky latex, which is the chief source of chicle.

The family *Sapotaceae*, to which the sapodilla belongs, contains 425 species, most of which are edible. Of these the various sapotes and star apples are of some importance.

Tamarind

The tamarind (*Tamarindus indica*) probably originated in tropical Africa or Southern Asia. It is a large tree, 80 ft. in height, with a dense crown, and is frequently grown for shade and ornamental purposes in semiarid regions. The fruits are brown pods, 3 to 8 in. in length. The pulp contains 12 per cent tartaric acid, as well as 30 per cent sugar, and so has a sour taste. The tamarind is extensively used in India and the Orient as a fresh fruit, in beverages, for preserving, and in medicine. The fruits were valued in Europe in the Middle Ages. The tamarind is commonly grown in the West Indies and also in southern Florida.

CHAPTER XX

SPICES AND OTHER FLAVORING MATERIALS

The story of spices, condiments, and the other flavoring materials is one of the most romantic chapters in the history of vegetable products. From the earliest time spices have been as eagerly sought after as gold. The craving for spices has been one of the great factors in human progress, and has done much to change the course of history and geography and to promote international relations. The discovery of new lands and of shorter trade routes and the colonization of spice-producing countries have resulted, in part, from this interest in aromatic plants. The quest for spices created a furor comparable only to the Crusades, and was one of the dominant factors in European history during the Middle Ages and as late as the sixteenth century. The use and cultivation of spices, however, go back to the beginnings of history. They have played a prominent part in all the civilizations of antiquity, in ancient China and India, in Babylon and Egypt, and in Greece and Rome. The majority of spices originated in the Asiatic tropics and were among the first objects of commerce between the East and the West. The first traders were the Arabs, who brought the products of southern India and the Spice Islands by caravan to Arabia, and thence to Europe. Later other countries took over the spice trade. For many years Venice was the leader. In the sixteenth century the Portuguese assumed control and held a virtual monopoly for 200 years. They were supplanted by the Dutch, who were supreme for many years. Today the British Empire shares with Holland most of the spice trade of the world.

In the olden days spices were put to many uses. They not only served to season insipid foods and give zest to an otherwise monotonous diet, but acted as preservatives as well. Their aromatic qualities were useful in overcoming the odors of bad food and unwashed humanity. They were used in beverages, in medicine, and even in lieu of money. Sought after by rich

and poor alike, and expensive because of the demand and the difficulty of obtaining them, they were the basis of many great fortunes made between 1300 and 1700 A.D.

The use of spices is not so widespread at the present time, but the United States still pays from $10,000,000 to $20,000,000 annually for crude spices, which are worth twice as much in the retail trade. The practice of importing the various aromatic substances in a crude state (Fig. 199) and converting them into a powdered form is still followed in an attempt to prevent adulteration and to insure the quality of the final product. Essential oils, obtained from these aromatics, are also imported in large amounts.

Spices cannot be classed as foods, for they contain little of nutritive value. They do, however, give an agreeable flavor and aroma to food, and add greatly to the pleasure of eating. They stimulate the appetite and increase the flow of the gastric juices. For this reason they are often referred to as food accessories or adjuncts. Whatever value they have is due to the presence of the essential oils, and occasionally to other aromatic principles.

The medicinal value of spices is not so great as was thought during the Middle Ages, but a considerable number of them are still official drugs in both Europe and America. They are used as carminatives and antiseptics and to disguise the unpleasant taste of other drugs. They also play an important part in many of the industries and are used in perfumery, soaps, incense, as dyes, in histology, and in various arts.

The majority of spices are still obtained from the tropics, chiefly from Asia. Africa supplies the grains of paradise, while tropical America furnishes vanilla, red pepper, and allspice. A small number occur in the cooler temperate regions of the Old World.

The classification of spices, as in the case of all plant products that contain essential oils, is very difficult and there are no sharp boundaries between the various groups. Usually all aromatic vegetable products that are used for flavoring foods and drinks are included under spices. In other cases the term "spice" is restricted to hard or hardened parts of plants, which are usually used in a pulverized state. Condiments are spices or other flavoring substances that have a sharp taste, and are usually

added to food after it has been cooked. Savory seeds are small fruits or seeds that are used whole. In the sweet or savory

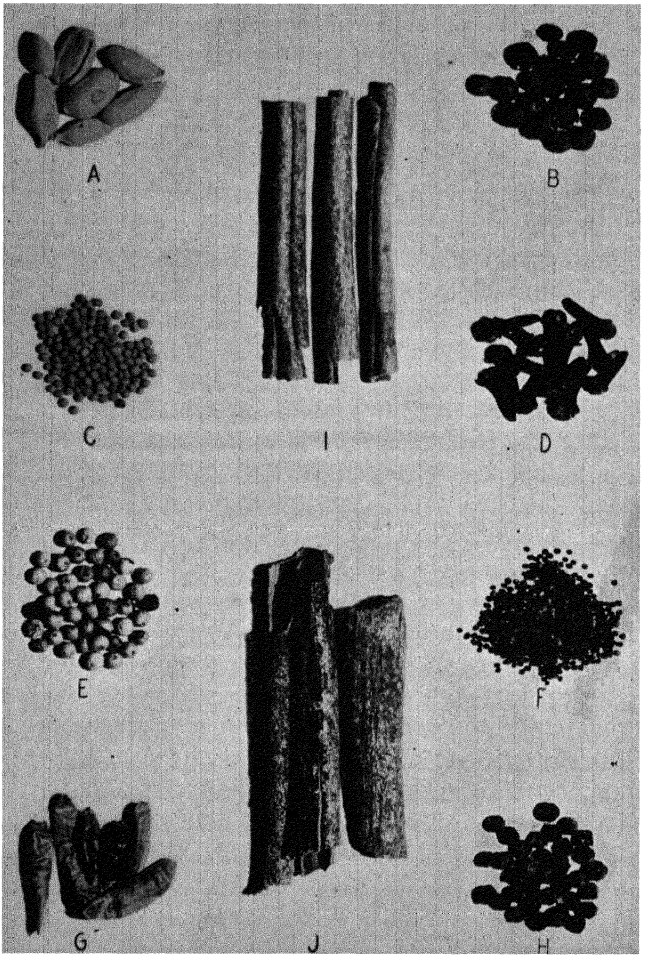


FIG. 199.—Crude spices. *A*, cardamom (*Elettaria Cardamomum*); *B*, allspice (*Pimenta officinalis*); *C*, white mustard (*Brassica alba*); *D*, cloves (*Eugenia caryophyllata*); *E*, white pepper; *F*, black mustard (*Brassica nigra*); *G*, capsicum (*Capsicum frutescens*); *H*, black pepper (*Piper nigrum*); *I*, cinnamon (*Cinnamomum zeylanicum*); *J*, cassia (*Cinnamomum Cassia*).

herbs, fresh or dried leaves are used for flavoring or garnishing. Essences are aqueous or alcoholic extractions of the essential oils. In view of the difficulty of distinguishing between

spices, condiments, and the other flavoring materials, it seems best to consider this group on a morphological basis—the nature of the plant part utilized. Of the hundreds of spices that are used today, only a few can be discussed. These will be treated under roots, barks, buds and flowers, fruits, seeds, and leaves and stems.

SPICES OBTAINED FROM ROOTS AND ROOTSTALKS

Angelica

The angelica plant (*Angelica Archangelica*) is a stout perennial herb with large pinnately compound leaves and small greenish-white flowers in terminal compound umbels. It is a native of Syria and now occurs in many parts of Europe and Western Asia in low ground. It even reaches boreal regions in Lapland and the Alps.

All parts of the plant are aromatic. The roots and fruits are dried and used for flavoring cakes, candy, and beverages, such as vermouth and the various bitters and liqueurs. The young stems and leafstalks are candied by steeping them in syrups of increasing strength. This candied angelica is much used for decorating and flavoring candy and cakes because of its attractive bright green color and aromatic taste. The oil, usually distilled from the fruits, is used in flavoring, perfumery, and medicine. Once grown in every garden, it is now cultivated only in Germany. Its use dates back to 1500 A.D.

Galangal

The **lesser galangal** (*Languas officinarum*) is a native of southern China, and was used at an early date in that country. It is a perennial herb with a raceme of showy flowers and ornamental foliage. The reddish-brown rhizomes have an aromatic, spicy odor and a pungent taste, like a mixture of pepper and ginger. Galangal was much more important formerly than it is today, but it is still used to some extent in cooking, in medicine, and for flavoring liqueurs and bitters.

The **greater galangal** (*Languas Galanga*), a larger plant of Java and Malaya, is also used somewhat for flavoring purposes.

Ginger

Ginger is the most important of the spices obtained from roots. It has had a long and interesting history. A native of South-

eastern Asia, it was early used in China and India, and was brought by caravans to Asia Minor before the time of Rome. It was among the first of the oriental spices to be known in Europe, where it was prominent early in the Middle Ages. For many years it was an important drug. It was the principal ingredient of a remedy for the plague, which was much used in England during the reign of Henry VIII. Today ginger is cultivated over a wider area than most spices, owing probably to the ease which the roots can be transported.

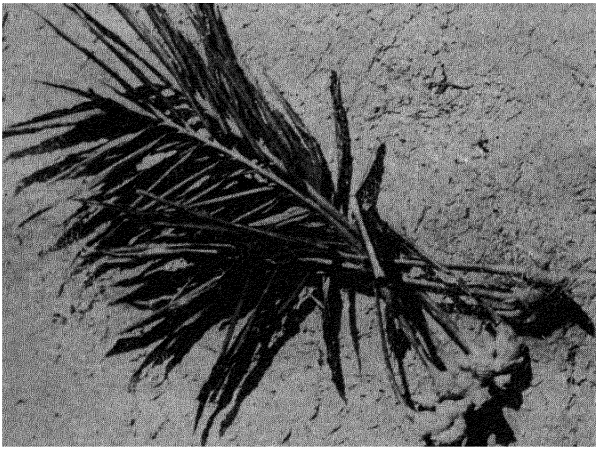


FIG. 200.—Two bunches of fresh ginger (*Zingiber officinale*) (*Photographed in Paoki, Shensi, China by F N Meyer Courtesy of the Arnold Arboretum.*)

The ginger plant (*Zingiber officinale*) is an erect perennial herb (Fig. 200) with thick scaly rhizomes that branch digitately and are known as "hands." The stem reaches a height of 3 ft. and is surrounded by the sheathing bases of the leaves. The flowers are borne in a spike with greenish-yellow bracts subtending the yellowish flowers, which have a purple lip. Ginger is cultivated for the most part in small home gardens. A rich moist soil, partial shade, and a strictly tropical climate are desirable. The plant is propagated by the rhizomes.

The rhizomes are pale yellow in color externally and a greenish yellow inside. They contain starch, gums, an oleoresin, and an essential oil as well. The several varieties differ in the content

of the latter two principles. The rhizomes are dug after the aerial parts of the plant have withered.

Ginger is prepared in two different ways. *Preserved* or *green ginger* is a product of southern China. Young juicy rhizomes are dried, cleaned, and boiled in water until tender. They are then peeled, scraped, and boiled several times in a sugar solution, and finally packed in a similar solution. Occasionally preserved ginger is prepared in a dry state by dusting the drying rhizomes with powdered sugar.

Dried or *cured ginger* is the product of the other ginger-growing countries. The rhizomes are cleaned, carefully peeled, and dried in the sun. They are sometimes parboiled in water or lime juice before peeling. This is the black ginger of commerce. White ginger is made by bleaching the rhizomes.

The aromatic odor of ginger is due to the essential oil, while the pungent taste is due to the presence of the nonvolatile oleoresin, gingerin. Ginger is used more as a condiment than as a spice. It dilates the blood vessels in the skin, causing a feeling of warmth, and increases perspiration, with an accompanying drop in temperature. For this reason it is much used in warm countries.

In medicine, ginger is used as a carminative and a digestive stimulant. It is extensively used in culinary preparations, such as soups, puddings, pickles, gingerbread, and cookies, and is an ingredient of all curries, except those used with fish. Ginger is exceedingly popular for flavoring beverages, such as ginger ale and ginger beer. It was formerly used for spicing wine and porter. The oleoresin is extracted and used in medicine and flavoring. The essential oil is also extracted. As this lacks pungency, cayenne pepper is usually added when it is used for flavoring purposes.

Ginger is grown chiefly in China, Japan, Sierra Leone, Jamaica, Queensland, and the Dutch East Indies. The United States imports crystallized ginger from China and dried ginger from Jamaica, India, and Sierra Leone.

Horseradish

The horseradish (*Rorripa Armoracia*) is a native of Southeastern Europe. The plant is extensively grown in both Europe and America (Fig. 201) and frequently escapes from cultivation

and becomes established. In many places it is a troublesome weed.

It is a tall hardy plant with glossy green toothed leaves and masses of small white flowers. The white cylindrical roots are usually dug in the fall. They are scraped or grated, and used as a condiment, either fresh or preserved in vinegar. The pungent taste is due to a glucoside, sinigrin, which is broken down in water by enzyme action. It is similar to mustard oil in its



FIG. 201.—A field of horseradish plants (*Rorripa Armoracia*). (*Courtesy of the Massachusetts State College.*)

properties. Horseradish is a valuable condiment and has been used for many years. It aids digestion and prevents scurvy.

Sarsaparilla

Sarsaparilla is obtained from the dried roots of several tropical species of *Smilax*, among them *S. medica* of Mexico, *S. officinalis* of Honduras, and *S. ornatus* of Jamaica. These plants are climbing or trailing vines with prickly stems and are found in dense moist jungles. They have a short thick rhizome and very long thin roots up to 10 ft. in length. This makes the collection of the roots a very arduous task. The roots contain a bitter principle much used for flavoring purposes. Sarsaparilla is

rarely used alone, but usually in combination with wintergreen and other aromatics.

Turmeric

Turmeric (*Curcuma longa*) combines the properties of a dyestuff and a spice, and has already been discussed in the former connection. It is native to Cochin China and is widely cultivated in the tropics of both hemispheres. Turmeric is especially popular in India, where 60,000 acres are devoted to it, and enormous quantities are used, as they have been for centuries. The plant is a robust perennial with a short stem and tufted leaves. The pale-yellow flowers are borne in dense spikes, topped by a tuft of pinkish bracts. The rhizomes, which are the source of the colorful condiment, are short and thick, with blunt tubers. They are cleaned, washed, and dried in the sun. Turmeric is very aromatic with a musky odor, and has a pungent bitter taste. It is used to flavor, and at the same time color, butter, cheese, pickles, and other foodstuffs. A considerable quantity is exported to Europe and America for this purpose. Turmeric is one of the principal ingredients of curry. Curry is not a single substance, but a compound of many spices. Each type of meat or other food requires its own particular curry. One popular recipe for a meat curry includes turmeric, coriander, cinnamon, cumin, ginger, cardamom, fenugreek, cayenne pepper, pimiento, black pepper, long pepper, cloves, and nutmeg. Another curry, used for fish, is made from turmeric, coriander, black pepper, cumin, cayenne pepper, and fenugreek.

Zedoary

Zedoary (*Curcuma zedoaria*) is a plant of similar habit with pale-yellowish or white flowers and showy crimson or purple bracts. It is much grown in India for the large tuberous rhizomes, which are sliced and dried. It was formerly an important spice, and is still used for flavoring liqueurs and curries. Its chief use today is in medicine, perfumery, and cosmetics.

SPICES OBTAINED FROM BARKS

Cassia

Cassia or Chinese cinnamon is one of the oldest of spices. It was known in China as long ago as 2500 B.C., in Egypt in the

seventeenth century B.C., and was familiar to all the peoples of the Mediterranean area at an early date. In the earlier records it is likely to be confused with cinnamon. Cassia is obtained from *Cinnamomum Cassia*, a native tree of Burma. It is an evergreen, 40 ft. in height, with smooth pale bark, small pale-yellow flowers, and a fleshy drupelike fruit. The tree is grown in southern China from seed, usually on terraced hillsides. Young trees from 6 to 10 years of age are cut down and cut up into short lengths. The bark is loosened, stripped off, and dried. Cassia bark (Fig. 199, *J*) reaches the markets in the form of dark-reddish-brown "quills," usually with some patches of grayish cork on the outside. It varies in quality, but is always very aromatic, though not so delicate as cinnamon. Among the several ingredients are tannin, sugar, starch, a dyestuff, a fixed oil, and the essential oil, which is distilled and used in medicine and flavoring.

Cassia buds are the dried unripe fruits. These contain the same essential oil, and should be used more. They are picked when only one-fourth grown and resemble little cloves.

There are several other sources of cassia of less importance. Indian cassia comes from *Cinnamomum Tamala;* Padang cassia, with smooth bark and no cork, from *C. Burmannii*, a tree of the Dutch East Indies. Large amounts of this cassia are imported in the United States. Oliver's bark (*C. Oliveri*) of Australia and Massoia bark (*C. Massoia*) of New Guinea are inferior substitutes.

Cassia bark and cassia oil are used in medicine, for flavoring purposes, and in soap, candy, and perfumery. The United States imports cassia chiefly from China and the Dutch East Indies.

Cinnamon

Cinnamon was discovered much later than cassia and immediately superseded the older spice. It was used by the natives long before it attracted the attention of the white man. It is a native of Ceylon, and is often called Ceylon cinnamon. For many years it was grown only in Ceylon and was a monopoly of the Portuguese, Dutch, and English in succession. Now the tree is grown in southern India, Burma, parts of Malaya, and to some extent in the West Indies and South America.

Cinnamomum zeylanicum, the source of cinnamon, is an evergreen shrub or small tree, with beautiful dark coriaceous leaves, numerous inconspicuous yellow flowers, and blackish berries. In cultivation young trees are cut back, and sucker shoots develop from the roots. These are long and slender and

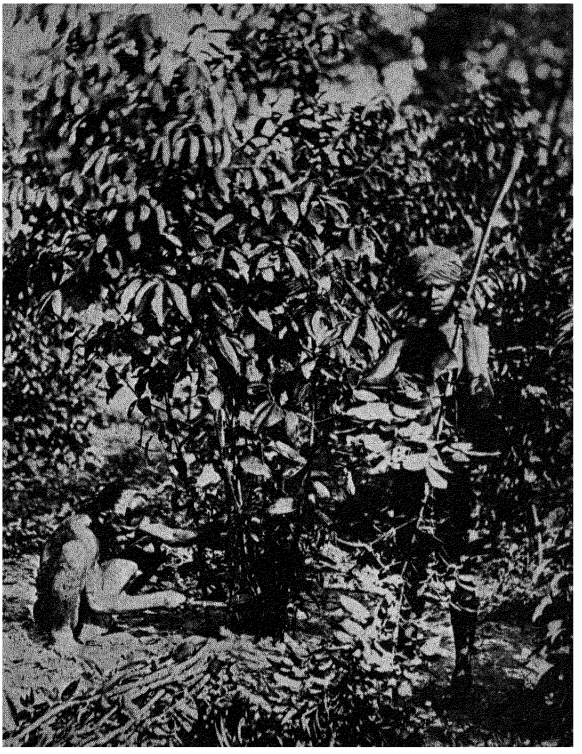


FIG. 202.—Cutting cinnamon (*Cinnamomum zeylanicum*) in Ceylon. (*Reproduced by permission of the Philadelphia Commercial Museum.*)

furnish the commercial product. They are cut twice a year (Fig. 202), the bark is removed, and the outer and inner portions are scraped off. After drying, compound quills are tied up, ready for shipment (Fig. 199, *I*). The waste is used as a source of oil of cinnamon. The leaves and roots of the plant are also aromatic, but the essential oil differs from that in the bark and is of little value. Cinnamon is one of the most popular spices used for flavoring foods. It is also used in candy, gum, incense,

dentifrices, and perfumes. The oil is used in medicine as a carminative, antiseptic, and astringent, and as a source of cinnamon extract.

Saigon cinnamon (*Cinnamomum Loureirii*) is grown in Cochin China. Its coarse bark is highly esteemed in China and Japan, and is also used in the United States, where it is recognized as an official cinnamon in the U.S. Pharmacopoeia.

Sassafras

Sassafras is not really a spice, but is a flavoring material of considerable importance. It is obtained from the bark on the roots of *Sassafras albidum* of eastern North America. The sassafras is a tree from 60 to 100 ft. in height, with characteristically lobed leaves and greenish-yellow dioecious flowers, produced before the leaves, and dark-blue drupes with red stalks. The spicy root bark was used by the Indians and early settlers. All parts of the plant are aromatic. The bark is gathered in the spring or fall, deprived of the outer corky layers, and dried. The supply comes chiefly from Virginia, Tennessee, and Kentucky. Sassafras is used for flavoring tobacco, patent medicines, root beer and other beverages, soaps, perfumes, and gum. Both sassafras bark and sassafras pith are used in medicine. The oil is used for flavoring and is one of the sources of artificial heliotrope.

SPICES OBTAINED FROM FLOWERS OR FLOWER BUDS

Capers

The caper bush (*Capparis spinosa*) is a trailing spiny shrub, a few feet in height. It is a native of the Mediterranean region and is cultivated in Southern Europe and the southern United States. The solitary berrylike fruits are borne on thick stalks. The unopened flower buds are gathered every morning and pickled in salt and strong vinegar. These capers are roughly spherical and round angled, and dark green in color. They have a very pungent taste and are used as condiments with meat and in sauces and pickles.

Cloves

Cloves are one of the most important and useful of the spices. They were in use as early as the third century B.C. in China, were

replaced the natural ones. Otto of roses and the oil from sweet violets, however, are still used. Floral syrups are also prepared and used for flavoring ices and beverages. Crystallized flowers are being used more and more. These are prepared by placing fresh flowers in baskets and allowing a sugar syrup to trickle over them until no more can be absorbed. They are then dried in the sun or with artificial heat. These confections have the flavor

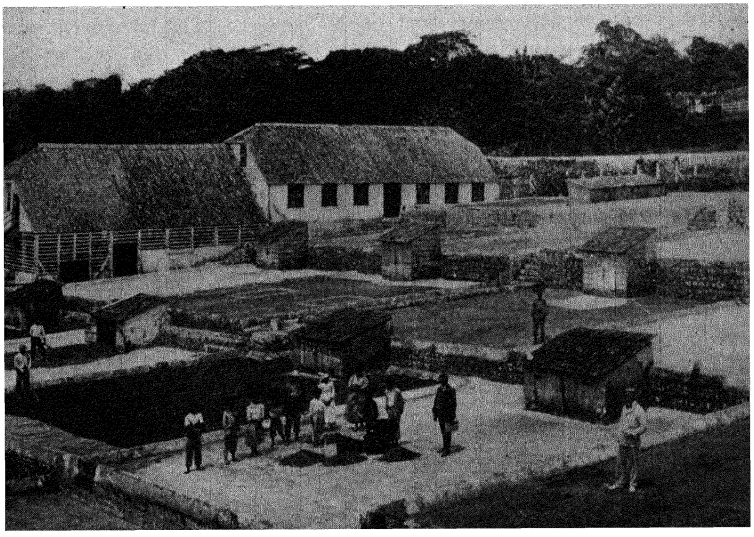


FIG. 204.—Drying allspice in Jamaica. The crude spice consists of the unripe fruits of *Pimenta officinalis* (*Reproduced by permission of the Philadelphia Commercial Museum.*)

imparted by the respective essential oils. The industry centers in Grasse, France. The flowers utilized include violets, rose petals, lavender, carnations, lilac, and orange.

SPICES OBTAINED FROM FRUITS

Allspice

The dried unripe fruits (Fig. 199, *B*) of *Pimenta officinalis*, a small tree native to the West Indies and parts of Central and South America, constitute the spice known as allspice, pimento, or Jamaica pepper. The name "allspice" is due to the fact that

its flavor resembles a combination of cinnamon, clove, and nutmeg.

The allspice tree is an evergreen, 20 to 30 ft. in height, with greenish-white flowers and purple fruits. Since the ripe fruits lose most of their aromatic qualities, the commercial product is collected when the berries are mature but still green. Branches are broken off and the fruits removed by hand or flails. The ripe and undersized berries are discarded, and the desirable ones are dried for several days (Fig. 204). They become wrinkled and turn a dull reddish brown, while the aroma becomes more pronounced. The allspice tree is so common in Jamaica that it does not have to be cultivated. It grows slowly and begins to bear when about seven years of age and continues for 12 years, with an average yield of 75 to 100 lb. per tree.

Allspice is used as a culinary spice alone, or in mixture. It is much favored for sauces, pickles, sausages, and soups. The extracted oil is used for flavoring and perfumery. The leaves contain an inferior oil of bay, which is sometimes used to adulterate bay rum. The wood is used for canes and umbrella handles.

Although grown to some extent in all the American tropics, allspice is so abundant in Jamaica that the island has a virtual monopoly, exporting from 4000 to 5000 tons annually.

Capsicum

America's most important contribution to the spices is capsicum or red pepper. This familiar condiment is obtained from the fruits of several different plants, all belonging to the genus *Capsicum*. This genus is native to tropical America and the West Indies. The capsicums are very old, extending back to pre-Inca days. Shortly after the voyages of Columbus, who found all the West Indian natives using red pepper, the spice reached Europe, and by 1600 it was widespread in the Eastern tropics. Today capsicums are grown all over the world, except in the colder parts, and in many countries they are the most important spice.

The long period of cultivation has resulted in many varieties, differing in habit and in the size, shape, color, and pungency of the fruit. Among these are the bell peppers, chilis, paprikas, pimientos, tabascos, and others. By some authorities these are

considered to belong to two or three distinct species, while others interpret them as derivatives of a single species, known variously as *Capsicum frutescens* or *C. annuum.*

The **sweet** or **bell peppers** (var. *grossum*) are herbs or slightly woody plants, 2 or 3 ft. in height, with ovate leaves, white flowers with a rotate corolla, and many-seeded fleshy fruits, which are technically berries. The fruits (Fig. 205) are large and puffy with a depression at the base, and are yellow or red in



FIG. 205.—Varieties of bell peppers (*Capsicum frutescens* var. *grossum.*) These sweet peppers are the mildest of the capsicums and are used as a fruit vegetable rather than a spice. (*Courtesy of Breck and Company.*)

color when ripe. These peppers are the mildest of all the capsicums, as the pungent principle is restricted to the seeds. They are more favored in the northern part of the United States, where they are used as a fruit vegetable rather than as a spice. Both green and ripe peppers are eaten raw in salads, or are cooked in various ways, stuffed peppers being especially popular. They are also used in pickles. The plants are grown as annuals or biennials, depending on the climate. They require a long season in which to develop, but even so are well adapted to cooler areas, for they will withstand a little frost.

The **paprikas** are European varieties with large mild fruits. Spanish paprika, which is better known as pimiento, produces attractive fruits with a characteristic flavor, but entirely lacking in pungency. These are preserved, and are used in cheese preparations and stuffed olives. They are also grown in California and Georgia. Hungarian paprika has long pointed fruits which are more pungent. These are dried and used for powdered paprika, which is a familiar condiment. Several grades are prepared, differing in pungency. Only the pericarps and seeds are used. The uses of paprika as a condiment and in cooking are too well-known to need mention. Perhaps the best known dish, in which paprika is an essential element, is Hungarian goulash.

The **chilis** (var. *longum*) or capsicums, as they are known in medicine, are strictly tropical and subtropical plants. They are more woody and taller, with small podlike berries and innumerable small flat seeds. The crimson or orange-red fruits (Fig. 199, *G*) are elongate, conical, somewhat flattened, and very pungent. The pungent principles are present in the flesh and rind as well as the seeds. These peppers are cultivated everywhere in the tropics. The African varieties are the hottest, but Japanese chilis are more favored for culinary purposes. The ripe fruits are dried in the sun and used whole or powdered. The ground fruits constitute the cayenne pepper or red pepper of commerce. Capsicum is used in medicine internally as a powerful stimulant and carminative and to prevent fever; it is used externally as a counterirritant. It is extensively used in such beverages as ginger ale because of its pungency. The culinary uses are too numerous to mention. These small peppers are especially favored in the American tropics, where they are used in *chili con carne*, tamales, and other local dishes. Pepper sauce is made by extracting the pulp by pressure and pickling in brine or strong vinegar. Tabasco sauce is pepper sauce made from a small variety grown in Louisiana.

The United States imports paprika from Hungary, and capsicum chiefly from Japan, British East Africa, and Mexico.

Juniper

The "berries" of the common juniper (*Juniperus communis*) are used as a flavoring material. The juniper is a small tree or

prostrate shrub with evergreen needlelike leaves and a berrylike cone, formed by the fleshy coalesced scales. The tree is a native of the cooler parts of Asia, Europe, and North America. The berries have a sweetish pulp with a characteristic ginlike aroma. They are purple in color, with a greenish bloom. They are dried and used in flavoring game and various meats, but more particularly for gin. The volatile oil that is extracted from crushed berries by steam distillation is also used for flavoring gin, and to some extent in medicine.

Pepper

Pepper has always been one of the most important of spices, and it is one of the most ancient. It has been highly esteemed in the East from time immemorial. It was an important commodity in Greece and Rome, and was the chief spice during the Middle Ages, when tributes were often levied in pepper. As early as 1180 the Guild of Pepperers was one of the leading trade guilds in England. It is interesting to note that London is still the center of the pepper trade. The high price of pepper was one of the chief incentives for the search for a sea route to India. Today no other spice is better known or more widely used.

Black pepper is the dried unripe fruit of *Piper nigrum*, a vine indigenous to India or the Indo-Malayan region. It is now cultivated everywhere in the Eastern tropics from Africa to India, Siam, the Philippine Islands, the East Indies, and the South Sea Islands. The pepper plant is a weak climbing or trailing shrub with adventitious roots, reaching a length of 30 ft. in the wild state. It has coriaceous evergreen leaves and very small flowers in catkins. The fruits are small one-seeded berrylike drupes, about 50 to a catkin. In ripening they change in color from green to bright red and then to yellow. Pepper requires a hot humid climate and at least partial shade. Various soils can be utilized. The plants are supported on posts or living trees (Fig. 206). When they are about 2 ft. in height, the tip is removed to promote the development of lateral buds. The crop begins to yield in two or three years and reaches full bearing in seven years. Propagation is by seed or cuttings from the tips of the vines.

For the preparation of the black pepper of commerce the fruits are gathered when at least a few of the berries in each spike are red. They are picked by hand. The spikes are dried in the sun or in smoke and are sometimes treated with boiling water preparatory to drying. When dry, the berries or peppercorns (Fig. 199, *H*) are rubbed off, winnowed, and packed for shipment. They are reddish brown or black with a wrinkled surface and measure 3 to 5 mm. in diameter.



FIG. 206.—Picking pepper in Singapore. The pepper plant (*Piper nigrum*) is a weak climbing shrub, and is usually supported on posts when under cultivation. (*Reproduced by permission of the Philadelphia Commercial Museum*)

White pepper is prepared from berries that are nearly ripe. They are picked and piled in heaps to ferment or are soaked in water. The pulp and outer coating of the seed are then removed. White pepper is a yellowish-grey color, and the surface is smooth (Fig. 199, *E*). Frequently white pepper is prepared from black peppercorns by grinding off the outer parts by machinery. Although not so pungent as black pepper, white pepper is preferred in the trade. Commercial ground pepper is often a blend.

The aromatic odor of pepper is due to a volatile oil, while the pungent taste is caused by an oleoresin. An alkaloid is also

present. Pepper stimulates the flow of saliva and the gastric juices and has a cooling effect. The culinary uses are numerous, and it is especially valuable as a condiment. Pepper itself as well as the oleoresin and alkaloid are used in medicine. The alkaloid is used as a source of synthetic heliotrope. The United States imports more pepper than any other spice.

Long Pepper

Long pepper is obtained from *Piper retrofractum* of Java and *Piper longum* of India. The former species, a climbing woody plant native to Malaya, is cultivated in Java, Bali, and adjacent islands. The latter is more shrubby. It is a native of India, Ceylon, and the Philippine Islands, and is grown chiefly in Bengal.

Long pepper was more highly esteemed by the Romans than black pepper and was also important in the Middle Ages. The tiny fruits are fused into cylindrical spikelike cones. These are collected when unripe and are dried quickly in the sun or over fires. Long pepper contains the same principles as black pepper, but is very aromatic and somewhat sweeter. It is grown in the same way as the ordinary pepper. It is almost a forgotten spice, except in the tropics, where it is extensively used in pickles, preserves, and curries.

Star Anise

Star anise is the fruit of a small evergreen tree (*Illicium verum*) which is probably a native of China. The star-shaped reddish-brown fruits consist of eight carpels, each with a hard shiny seed. Both the seeds and the fruit are highly aromatic with a flavor of anise. The plant is cultivated from seed only in southern China and Indo-China. It is not grown more frequently because of its special climatic requirements and its slow and hazardous development. The tree yields at from 6 to 100 years of age, often producing two crops a year. The fruits are collected before they are ripe and are dried, or are immediately distilled for the oil. Star anise is used as a culinary spice only in the East. It is often chewed to sweeten the breath and aid digestion. The oil is used in medicine as a carminative, expectorant, and flavoring material, and also in liqueurs, aperitifs, and perfumery.

Vanilla

A climbing orchid, *Vanilla fragrans*, native to the hot moist forests of tropical America, is the chief source of vanilla. This favorite flavoring material is obtained from the cured, fully grown, but unripe fruits. Its use antedates the discovery of America. The Spaniards, who found the Aztecs using it to flavor chocolate, carried vanilla to Europe. It soon reached the Eastern tropics and was cultivated in many places.

The plant is a climbing vine with fleshy adventitious roots, large succulent leaves, and greenish-yellow flowers. The fruits

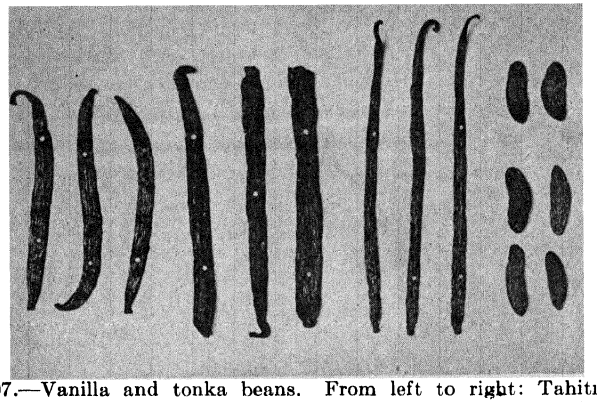


FIG. 207.—Vanilla and tonka beans. From left to right: Tahiti vanilla; Pompona vanilla; Mexican vanilla; tonka beans, a substitute for vanilla. Tahiti and Mexican vanilla come from *Vanilla fragrans*, while Pompona vanilla is the fruit of *V. Pompona*. Tonka beans are the seeds of *Dipteryx odorata* and *D. oppositifolia*. (*Reproduced by permission from Youngken, Textbook of Pharmacognosy, P. Blakiston's Son & Company.*)

are long, thin, yellow, podlike capsules, known as vanilla beans. Vanilla is a strictly tropical species and requires a hot climate with frequent rains. In cultivation it is grown from cuttings, and is trained on posts or living trees. The flowers are artificially pollinated by hand.

The flavor and aroma are not present in the pods until they have been cured. The unripe fruits are picked at just the right time and submitted to a sweating process. They are exposed to the sun during the morning, and are then protected by blankets during the afternoon, while at night they are placed in airtight boxes. During this curing process a glucoside is changed by

enzyme action into a crystalline substance, vanillin, which possesses the characteristic odor and flavor. The pods (Fig. 207) become tough and pliable and very fragrant, and turn dark brown in color. Often crystals of vanillin appear on the surface. Vanilla is cultivated in many tropical countries, regions with an island climate being particularly favorable. Mexico, the Seychelles Islands, Madagascar, the Comoro Islands, Reunion, Tahiti, and Gaudeloupe are the chief producing areas. West Indian or Pompona vanilla is obtained from *Vanilla Pompona*, a species with shorter, thicker pods.

Vanilla is used in flavoring chocolate, ice cream, candy, puddings, cakes, beverages, etc. Occasionally the beans are used, but more often an extract is prepared by extracting crushed beans with alcohol. The manufacture of synthetic vanillin from eugenol, which occurs in clove oil, has seriously threatened the vanilla industry, but the demand for the natural product is now increasing. Several other plants have been used as substitutes for the true vanilla, but they are of little value.

Savory "Seeds"

The great family of the *Umbelliferae* is characterized, among other things, by the possession of aromatic fruits. These fruits (Fig. 208) consist of two one-seeded carpels, or mericarps, with numerous oil ducts containing essential oils. The mericarps separate readily and are so seedlike in appearance that they are commonly called seeds. These savory "seeds" are usually used whole for flavoring purposes. The commonest commercial species are anise, caraway, celery, coriander, cumin, dill, and fennel.

Anise.—Anise (*Pimpinella Anisum*) is one of the earliest aromatics to be mentioned in literature. It was well-known to the Hebrews, Greeks, and Romans and was highly valued during the Middle Ages for its real or reputed medicinal value. The plant (Fig. 209) is an annual, about 2 ft. in height, with simple or ternate basal leaves and once- or twice-pinnate stem leaves. The small fruits (Fig. 208, *D*) are grayish-brown and covered with short hairs. Anise is extensively cultivated in Europe, Asia Minor, India, and parts of South America. It is a native of the Mediterranean region. Anise is used for flavoring cakes, curries, pastry, and candy. The oil is distilled and used in

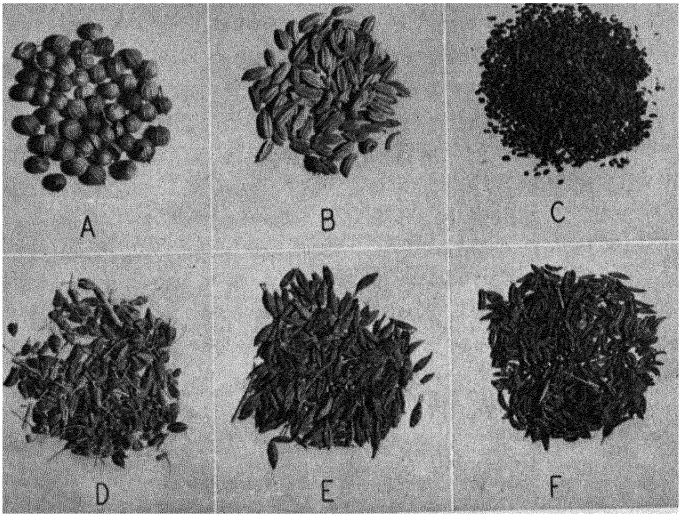


FIG 208.—Savory "seeds," the fruit of various members of the *Umbelliferae* *A*, coriander (*Coriander sativum*), *B*, fennel (*Foeniculum vulgare*), *C*, celery (*Apium graveolens*), *D*, anise (*Pimpinella Anisum*), *E*, cumin (*Cuminum Cyminum*); *F*, caraway (*Carum Carvi*)

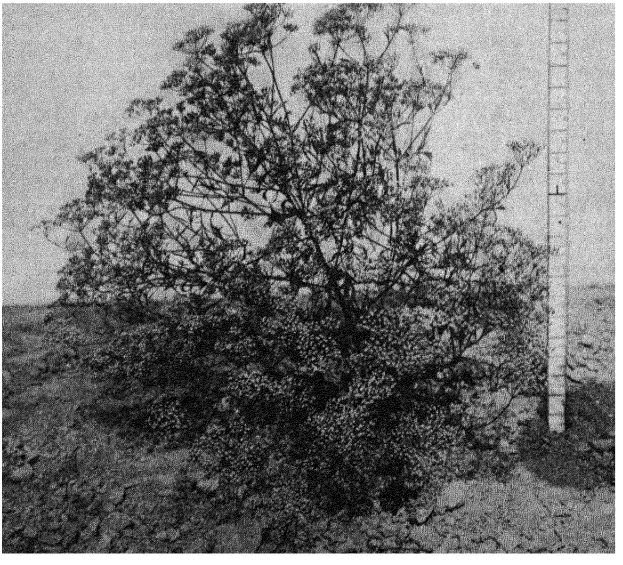


FIG. 209.—An anise plant (*Pimpinella Anisum*) showing flowers and fruit.

medicine, perfumery, soaps and other toilet articles, and beverages. The liqueur anisette is well-known.

Caraway.—Caraway (*Carum Carvi*) is the most important of the umbelliferous fruits. The plant is a native of Europe and Western Asia, but is now widely distributed in temperate regions of both hemispheres, often occurring as a weed. It has been cultivated since before the time of the Lake Dwellers in Europe. Caraway is a perennial with thick roots, compound leaves with linear segments, and small white flowers. The brown fruits (Fig. 208, *F*) are slightly curved and tapering. These "seeds" are used in perfumery, medicine, and beverages, such as the liqueur kümmel. Caraway is grown commercially throughout Northern Europe.

Celery.—The "seeds" of the celery (*Apium graveolens*), already discussed under vegetables, are much used for flavoring. These fruits (Fig. 208, *C*) are small and dark brown with a pronounced celery flavor. The oil has some medicinal value, but is used chiefly for flavoring in the form of an extract. Salt, flavored with celery-seed oil or the ground seeds, is in great demand for culinary purposes.

Coriander.—Coriander is another very old flavoring substance. It is mentioned in Egyptian, Sanskrit, Hebrew, and Roman literature. During the Middle Ages it had many curious uses, such as love potions, incense, etc. The plant (*Coriandrum sativum*) is a native of the Mediterranean region, and is extensively grown in Europe, Morocco, and India. It is a rank-smelling perennial, 3 ft. in height, with small white or pinkish flowers. The lower leaves have broad segments, while the upper are very narrow. The globular yellow-brown fruits (Fig. 208, *A*) have an unpleasant odor when fresh. The dried fruits, however, are pleasantly aromatic and serve as a common flavoring substance for both sweet and savory dishes, especially in Europe and India. The fruits are often candied in a sugar solution and sold as "sugar plums." Oil of coriander is used in medicine and in flavoring beverages, such as gin, whisky, and various liqueurs. The extract or essence is a better flavoring substance than either the dried fruit or the oil.

Cumin.—Cumin (*Cuminum Cyminum*) has been cultivated for so long that it is difficult to say where it is native. Like so many others of this group, it probably originated in the Mediter-

ranean area. The plant is an attractive little annual with small pinkish flowers. The elongated oval fruits (Fig. 208, *E*) are light brown in color and hot and aromatic. Cumin was highly prized by the ancients and is frequently mentioned in the Bible. Today it is extensively grown in Southern Europe and India.

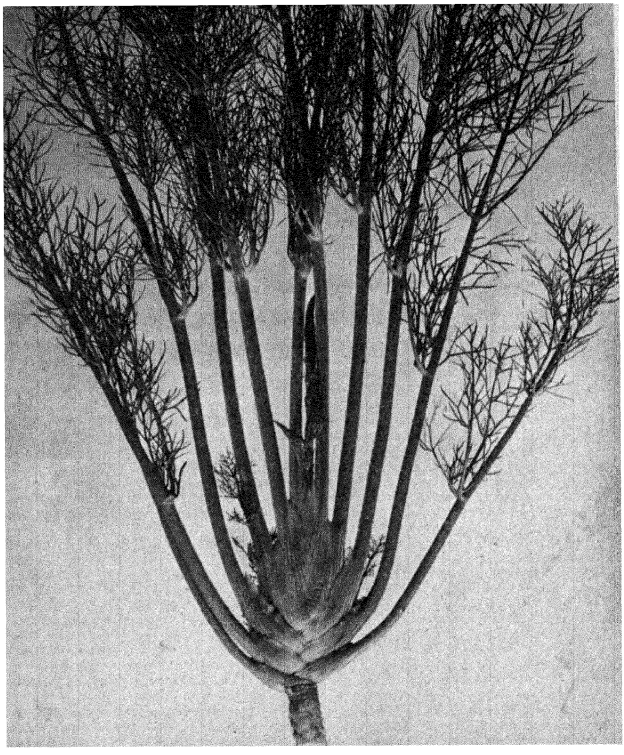


FIG. 210.—Sweet or Florence fennel (*Foeniculum vulgare* var. *dulce*). The thickened and blanched leafstalks of this variety are used as a vegetable. (*Courtesy of Breck and Company*)

The fruits are used in soup, curries, cake, bread, cheese, and pickles, and are often candied. The oil is used in perfumery and for flavoring beverages.

Dill.—Dill (*Anethum graveolens*), a native of Eurasia, still occurs spontaneously in many places. It was grown in Greece, Rome, and ancient Palestine, where it was held in high repute.

It is now cultivated in Europe, India, and the United States. Dill is a small annual or biennial with light-green leaves and yellow flowers. The "seeds" are oval, light brown, and much compressed. In the United States dill is used chiefly for flavoring pickles. In France, India, and other countries it is much used in soups, sauces, and stews and for other culinary purposes. Both the seeds and the oil are used in medicine. In India and Russia the leaves are also utilized.

Fennel.—Fennel (*Foeniculum vulgare*) has had a long and interesting history. A native of the Mediterranean region, it has spread all over the world and often occurs as an escape from cultivation. It was known to the ancient Chinese, Hindus, and Egyptians as a culinary spice. The Romans cultivated it for its aromatic fruits and edible shoots. It is indispensable in modern French and Italian cooking. All parts of the plant are aromatic and can be utilized in various ways. Fennel is a tall perennial with finely divided leaves and yellow flowers. The "seeds" are oval and greenish or yellowish brown (Fig. 208, *B*). They are used in cooking and for candy and liqueurs. The oil is used in perfumes, soaps, and medicine. The thickened leafstalks (Fig. 210) of one variety, finochio or Florence fennel (var. *dulce*), are blanched and used as a vegetable.

SPICES OBTAINED FROM SEEDS

Cardamom

For centuries the highly aromatic seeds of the cardamom (*Elettaria Cardamomum*) have been an important spice in the Orient. The plant is a native of India, and is cultivated chiefly in that country and Ceylon, although it has been introduced into other tropical countries. It is a perennial herb, 6 to 12 ft. in height, with long lanceolate leaves with sheathing bases. The white flowers, with a blue and yellow lip, are borne on a separate elongated stalk. The fruits, which are triangular capsules, are borne the year round. The small seeds (Fig. 199, *A*) are light colored and have a delicate flavor. They are usually kept in the fruit until needed, for the flavor is better. In other cases, seeds of either wild or cultivated plants are gathered when dead ripe and dried in the sun. Cardamoms are used in curries, cakes, pickles, and for other culinary purposes, as well as in

medicine. They are a favorite masticatory in India. The oil is used somewhat in cooking and in flavoring beverages.

Fenugreek

Fenugreek (*Trigonella Foenum-graecum*) is an annual legume with white flowers and long slender pods with a pronounced beak. It is a native of Southern Europe and Asia. The plant is grown for forage and for ornamental purposes. The small seeds are used in India for curries, in dyeing, and in medicine. The extract is used with other aromatic substances in making an artificial maple flavoring.

Grains of Paradise

Aframomum Melegueta, a perennial herb of West Africa, is the source of the aromatic seeds known as grains of paradise. This plant has large rootstalks which send up an erect stem, 8 ft. or so in height, with long fragrant leaves and showy yellow orchidlike flowers in dense spikes. The fruits are orange pear-shaped capsules, and contain the golden-brown seeds with a distinctive aroma. These seeds are very pungent and during the Middle Ages rivaled pepper in popularity. They are still used somewhat in medicine and for flavoring beverages, and deserve wider recognition. The seeds of various species of *Amomum* are sometimes utilized as substitutes.

Mustard

Mustard was well-known to the ancients. It is frequently mentioned in the Bible and in Greek and Roman writings. During its long history it has had many curious uses. Today mustard is grown as a field crop in most temperate regions, especially in North America, Europe, China, and Japan. Although cultivated chiefly for the seeds, the tops are used somewhat as pot herbs and salad plants. Two species are utilized.

White Mustard (*Brassica alba*) is a freely branching annual, 2 to 6 ft. in height, with yellow flowers, hairy lobed leaves, and a bristly pod with a long beak. The small round seeds (Fig. 199, *C*) are yellow on the outside and white within. They contain, among other substances, mucilage, proteins, a fixed oil, and a glucoside, sinalbin. When ground seeds are treated with water, this glucoside is broken down through enzyme

activity and yields a nonvolatile sulphur compound with a characteristic sharp taste and pungency. White mustard is used in medicine and as a condiment. The fixed oil is expressed and used externally as a counterirritant. It can also be utilized as a lubricant and illuminant.

Black mustard (*Brassica nigra*), also a native of Eurasia, is grown more commonly in almost all civilized countries. It is a common weed in the United States, and is cultivated commercially in many places, especially in California and Kentucky. The plant is smaller than the white mustard, and has smooth pods with dark-brown seeds (Fig. 199, *F*), which are yellow inside. Black-mustard seed has the same general constituents as white-mustard seed. The glucoside, sinigrin, however, yields on decomposition a volatile oil containing sulphur, which is responsible for the pungent, aromatic odor and flavor. This essential oil is very powerful and dangerous to handle as it readily blisters the skin. It also attacks the membranes of the nose and eyes. When well diluted it is used in medicine as a counterirritant, and to some extent in condiments. The expressed fixed oil has a mild taste. It is used in soapmaking and medicine.

Ground mustard is much used as a condiment and in preparing pickles, sardines, salad dressing, etc. It has a stimulating effect on the salivary glands and also increases the peristaltic movements of the stomach. Mustard and warm water form an efficient emetic. The more pungent black mustard is preferred on the continent of Europe, while white mustard is more popular in England. Ground mustard, however, is usually a combination of the two kinds. The familiar mustard paste is prepared by treating ground mustard with salt, vinegar, and various aromatics.

Indian mustard (*Brassica juncea*) is used in India and parts of Europe as a spice and in cooking. Its properties are similar to those of black mustard. The fixed oil is expressed and is used in cooking and to anoint the body.

Nutmeg and Mace

Nutmeg and mace are both obtained from *Myristica fragrans*, a native of the Moluccas or Spice Islands, and now grown in the tropics of both hemispheres. It is doubtful whether these spices, which are now so popular, were known to the ancients. They

had reached Europe, however, by the twelfth century. Upon the discovery of the Spice Islands in 1512, the Portuguese obtained a monopoly of nutmeg and mace, which was later wrested from them by the Dutch. At a later date trees were smuggled into French and British possessions and the monopoly was broken.



growing in the Peradeniya Botanical Garden, Ceylon. Both nutmeg and mace are obtained from the seeds of this species. (*Courtesy of the Arnold Arboretum.*)

The nutmeg tree is a handsome evergreen with dark leaves and reaches a height of 30 to 60 ft. It is normally dioecious, with small pale-yellow flowers that are fleshy and aromatic. The ripe fruits (Fig. 211) are golden-yellow and resemble apricots or pears. They gradually dry out and, when dead ripe, the husk splits open revealing the shiny brown seed covered with a bright-red branching aril. Inside the seed is the kernel, which is the nutmeg of commerce. The aril is the source of mace.

The nutmeg is propagated from seed in nurseries and later transplanted. It requires a hot moist climate and thrives best when near the sea, so that islands are very favorable for its growth. The trees come into full bearing when about 15 years of age and continue for 10 or 20 years. The yield is very high, a large tree furnishing from 3000 to 10,000 nutmegs annually. Fruits are produced all the year round. After the husks split open, the fruits are picked, the pericarp is removed, and the mace is stripped from the shell, flattened, and dried. It turns a yellowish brown. The seeds are dried and the shell cracked off. The kernels are removed, sorted, and often treated with lime to prevent insect attack.

Mace is one of the most delicately flavored of spices and is used with savory dishes and in making pickles, ketchup, and sauces.

Nutmegs have been used medicinally and as a culinary spice for a long time. Grated nutmeg is used with puddings, custards, and other sweet dishes, and with various beverages. A jelly is made from the fresh husks of the ripe fruit. An essential oil is extracted for use in medicine and as a flavoring agent. This oil contains a highly toxic substance, myristicin, and can be used only in small amounts. Caution must also be exercised in the use of nutmeg and mace. Nutmeg oil is also used in the perfume and tobacco industries and in dentifrices. Nutmegs contain a fixed oil, known as nutmeg butter, the uses of which have already been discussed.

Tonka Beans

Two species of tropical South American trees (*Dipteryx odorata* and *D. oppositifolia*) are the source of tonka beans, which are becoming increasingly important as substitutes for vanilla. The large trees have curious egg-shaped fruits with a hard shell and pulpy flesh surrounding a single seed. The natives collect the fruits, break them open, and dry the seeds (Fig. 207). These resemble Jordan almonds and have a black wrinkled surface. They contain a crystalline substance, coumarin, which is of considerable importance in the manufacture of perfumes. The odor is that of new-mown hay, and closely suggests vanilla. The beans, or the extract, are used for flavoring snuff, tobacco,

and sachet powders, and as a substitute for vanilla in cocoa, candy, and ice cream.

SPICES OBTAINED FROM LEAVES

The aromatic and sweet-smelling leaves of many plants have long been used for flavoring materials and for their medicinal value. The old-fashioned herb garden with its fragrant plants is returning to popularity and the savories or sweet herbs may again be as familiar as they were a century ago. Many of these plants belong to the mint family, which is characterized among other things by its aromatic odor, square stems, and small bilabiate corollas. Among the more important mints that are used as flavoring materials may be mentioned balm, basil, marjoram, peppermint, sage, savory, spearmint, and thyme.

Balm

Balm (*Melissa officinalis*) is a perennial herb of Southern Europe, which has been introduced into all temperate climates. It has been cultivated for over 2000 years and was well-known to the Arabs, Greeks, and Romans. The leaves are used in soups, stews, sauces, dressing, and salads. The essential oil has a lemonlike taste and is used in beverages. The flowers have long been an important source of honey.

Basil

Sweet basil (*Ocimum Basilicum*) is probably a native of India and Africa. It has been used in the former country for centuries as a condiment, and has long been popular in England because of its aromatic qualities. The leaves are used in stews and dressings and as an ingredient of mock turtle soup and the famous Fetter Lane sausages. Basil is also very popular in French cookery. The golden-yellow essential oil is used in perfumery and various beverages.

Marjoram

Sweet marjoram (*Marjorana hortensis*), a native of the Mediterranean region, is another savory herb of great antiquity. It is a sacred plant in India, and is popular in both Europe and the United States. The leaves, flowers, and tender stems are used for flavoring syrups, stews, dressings, and sauces. The

essential oil is used for soap and perfumes. Pot marjoram (*Origanum vulgare*) is also used to some extent.

Peppermint

Peppermint (*Mentha piperita*) is one of the most important of the aromatic herbs. It is a perennial plant found wild in moist ground in the temperate parts of Europe, Asia, and America. It is cultivated in Europe and has been an important crop plant in America for 100 years. Peppermint was first grown in New York, but now Michigan, Indiana, and the Pacific Northwest are the leading states. Mucky soils unsuited to other types of agriculture are utilized. The crop is harvested with mowing machines when in blossom and after drying is hauled to distilleries. Peppermint has a refreshing odor and a persistent cooling taste. The leaves are used to some extent for flavoring purposes, but the oil is of much greater importance. This is used to flavor gum, candy, and various pharmaceutical preparations. It is valuable in both internal and external medicine and in the perfume and soap industries. Because of its penetrating odor it is often used to detect leaks in pipes. Between 350,000 and 400,000 lb. of peppermint oil are produced in the United States. Peppermint camphor or menthol, a derivative of the oil, is a valuable antiseptic and is much used in the treatment of colds.

Japanese peppermint (*Mentha arvensis* var. *piperascens*) is extensively cultivated in Japan and the United States as a source of menthol. Although the menthol content is higher than in peppermint, both the oil and the camphor are very bitter and so are less valuable.

Sage

Sage (*Salvia officinalis*) has long been esteemed as a spice for use in making stuffing for fowl, meats, and sausage. It is a shrublike herb (Fig. 212) of the Mediterranean region and is widely cultivated. The greyish-green hairy leaves are very aromatic. It has been used for its reputed health-giving qualities since the time of the Romans. Oil of sage is used in perfumery.

Savory

Summer savory (*Satureja hortensis*), a native of the Mediterranean countries, is now grown all over the world. It is culti-

vated in Ohio, Illinois, and several of the Western states. The leaves are strongly aromatic, with a warm bitter taste. Formerly savory was used for flavoring cakes, candy, and puddings, but now it is used in dressing, sauces, and gravies and similar culinary products. The Romans used savory as a pot herb as well as flavoring material.



FIG 212.—Leaves and inflorescences of sage (*Salvia officinalis*). (*Photo by H. W. Youngken.*)

Winter savory (*S. montana*) was formerly a popular flavoring herb in Europe.

Spearmint

Spearmint (*Mentha spicata*), a native of temperate Europe and Asia, has spread all over the world. It is very common in the United States in wet places. Spearmint has been known since Biblical times. Both fresh and dried leaves are used for mint sauce and jelly and to flavor soups, stews, sauces, and beverages, such as mint juleps. The plant (Fig. 213) resembles peppermint, but has longer and lighter colored leaves and more pointed

spikes. It also has a milder flavor. Spearmint is cultivated to some extent.

Thyme

Thyme (*Thymus vulgaris*) is a native of the Mediterranean region, where it is still very common as a wild plant. It is cultivated in most countries and often escapes. Thyme was

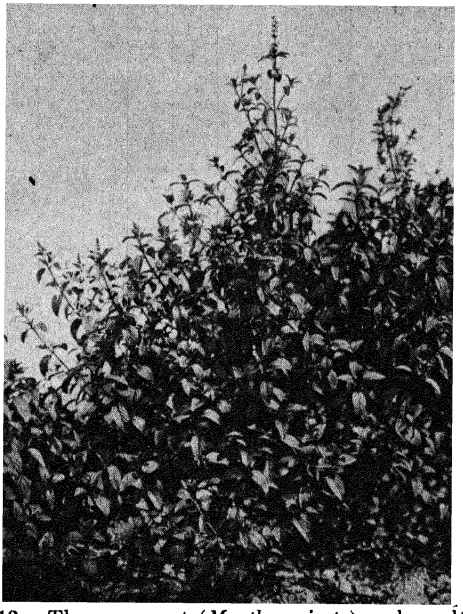


FIG. 213.—The spearmint (*Mentha spicata*) under cultivation.

used by the Greeks as an incense in their temples and by the Romans in cooking and as a source of honey. Today the fresh or dried green parts of the low shrubby plant are used in soups, sauces, dressings, and gravies. The oil is used in perfumery. Thymol, a derivative of the oil, is used in mouthwashes, tooth pastes, and as an internal medicine. It is also useful in industry.

Bay

The sweet bay (*Laurus nobilis*) is a small tree native to Asia Minor. It is very ornamental and is often cultivated. The leaves constituted the laurel of antiquity, the symbol of victory. They are bitter and aromatic and are much used in cooking. Bay is extensively grown in Europe, where the leaves are used in

soups, puddings, and other culinary products. It is an ingredient of the "bouquet," the small bunch of sweet herbs used extensively by the French. The essential oil was formerly used in medicine. Bay leaves also contain a fixed oil.

Parsley

Parsley (*Petroselinum hortense*) is one of the most familiar and widely cultivated of the garden herbs. It is a native of the rocky

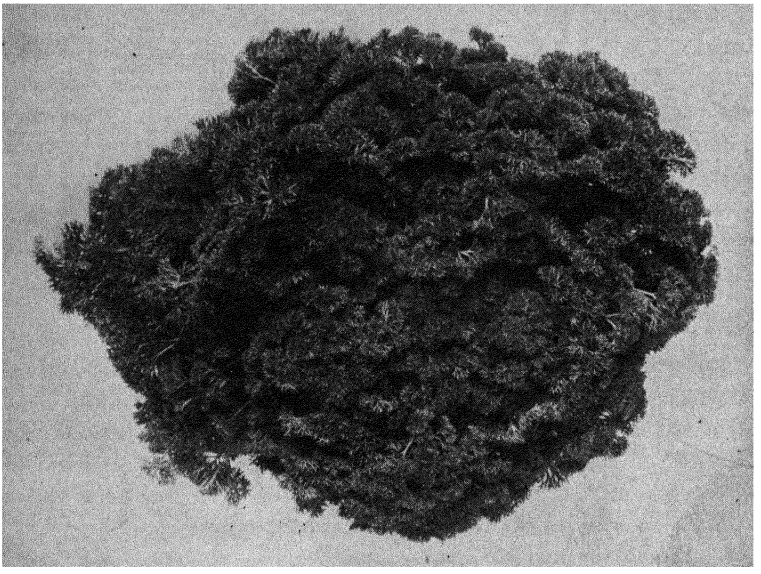


FIG. 214.—Parsley (*Petroselinum hortense*), one of the most familiar of the garden herbs. (*Courtesy of Breck and Company.*)

shores of the Mediterranean, but is found escaped from cultivation in all moist cool climates. The plant is a biennial or short-lived perennial, which produces during the first year a dense tuft of dark-green, finely divided leaves (Fig. 214). The leaves are used as a garnish and for flavoring soups, omelets, and stuffing. In some parts of Europe the tops are used for pot herbs and the roots as boiled vegetables.

Tarragon

Tarragon (*Artemisia Dracunculus*), a small herbaceous perennial of Western Asia, is widely grown in Europe for its pungent,

aromatic leaves, which are extensively used in making vinegar and pickles. It is also used for seasoning soups, salads, and various meat preparations. The tender shoots can also be utilized. The essential oil is used to perfume toilet articles.

Wintergreen

Wintergreen or checkerberry is an important flavoring material in the United States. The original source of this material was *Gaultheria procumbens*, a low creeping evergreen plant of eastern North America. The leaves contain a glucoside which breaks down in water to form methyl salicylate or oil of wintergreen. The oil is distilled from the leaves in copper stills. It was formerly an important industry in New England, and is now carried on chiefly in Pennsylvania. The sweet birch (*Betula lenta*) contains the same glucoside in its bark, and the young twigs and bark of this plant have almost entirely displaced the checkerberry as the source of oil of wintergreen. The oil is used in medicine and in flavoring candy and soft drinks.

Borage

Borage (*Borago officinalis*), a native of Europe and Northern Africa, is a coarse annual with very rough hairy leaves and stem. It occurs all over the world as a weed. Although but little used in the United States, borage is a favorite flavoring material for beverages in England. It is also utilized as a pot herb and in salads. The flowers are much sought after by bees.

Minor Savory Leaves

The following species contain aromatic oils and are used to some extent in medicine and for flavoring purposes. Among the mints may be mentioned: catnip (*Nepeta Cataria*), clary (*Salvia Sclarea*), hyssop (*Hyssopus officinalis*), and European pennyroyal (*Mentha Pulegium*). Species belonging to other families include: chervil (*Anthriscus Cerefolium*), lovage (*Levisticum officinale*), rue (*Ruta graveolens*), and tansy (*Tanacetum vulgare*).

OTHER SPICES AND FLAVORING MATERIALS

Several plants that furnish spices or flavoring materials have already been discussed in other connections. These include

almonds, calamus root, chives, cubebs, garlic, hoarhound, lavender, lemon, lime, orange, orris root, pistachio, poppy seeds, rosemary and sesame.

1935 IMPORTS OF IMPORTANT CRUDE SPICES

	Pounds		Pounds
Allspice	4,127,822	Ginger	3,404,069
Anise	490,627	Ginger, candied	1,093,124
Capsicum	1,611,654	Mace	702,627
Caraway	6,168,202	Marjoram	114,004
Cardamom	168,583	Mustard, seeds	7,770,861
Cassia	10,093,196	Mustard, ground	1,025,580
Celery	1,444,022	Nutmeg	4,420,911
Cinnamon	850,356	Paprika	6,585,054
Cloves	3,774,555	Pepper, black	33,085,593
Clove stems	328,397	Pepper, white	4,748,307
Coriander	1,618,322	Sage	1,446,143
Cumin	986,283	Sarsaparilla	109,055
Curry	34,453	Thyme	107,355
Fennel	310,989	Tonka beans	514,741
Fenugreek	511,732	Vanilla	828,625

CHAPTER XXI

BEVERAGE PLANTS AND BEVERAGES

NONALCOHOLIC BEVERAGES CONTAINING CAFFEINE

Beverages that contain caffeine are used the world over for their stimulating and refreshing qualities. As in the case of the cereals, each of the ancient centers of agriculture and civilization had its own beverage plant. Coffee, which originated in regions adjacent to Southwestern Asia, is now used by one-third of the world's population. Tea, which is associated with Southeastern Asia, is used by fully one-half the population of the world. Cocoa, a product of tropical America, today serves as both food and drink for over 300,000,000 people. In addition to these familiar beverages, there are others that are less widely known, but equally important. These include maté, the principal drink of 15,000,000 South Americans; cola, a favorite beverage and masticatory with millions of Africans; khat, used by the Arabs; and guarana, another South American drink, which has a higher caffeine content than any other beverage.

Caffeine is an alkaloid and, like others of this group of plant products, has definite medicinal values, acting as a diuretic and nerve stimulant. Although, as in the case of other drugs, caffeine is harmful in large quantities, it is present in these beverages in such small amounts, rarely over 2 per cent, that the average adult experiences no ill effects from their moderate use. Excessive indulgence should be avoided, and, in the case of sufferers from nerve disorders and of children, caffeine-containing beverages should be used sparingly, if at all.

Coffee

Coffee is the most important beverage plant from a commercial standpoint, in spite of the fact that more people use tea. The world output of coffee has been as high as 3,000,000,000 lb. with a value of over $500,000,000.

The coffee plant is considered to be a native of Abyssinia, and coffee must have been used in that country from very early times. It was carried to Arabia about 500 years ago, and for two centuries Arabia supplied the world. The plant was gradually introduced elsewhere in the tropics, and reached Ceylon and Java by 1700, the West Indies in 1720, and Brazil in 1770. Coffee

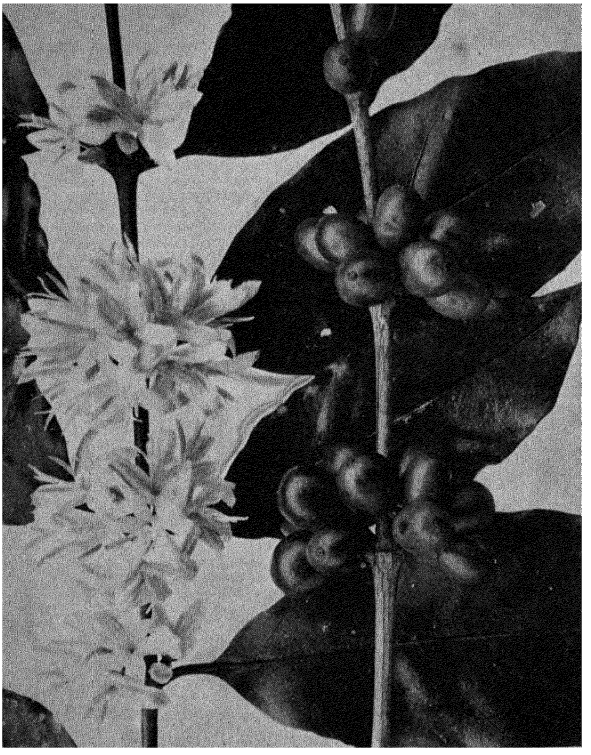


FIG 215.—Flowers and fruit of the coffee (*Coffea arabica*)

has been in general use as a beverage for only about 250 years. From Arabia it spread to Egypt and Palestine, and thence to Constantinople. It reached Venice in 1615, Paris in 1645, and London in 1650. In both France and England coffee enjoyed widespread popularity for a time and led to the establishment of the famous coffeehouses, the gathering places of the literary men of the day. In spite of the fact that today the United States is the greatest coffee-consuming country, the beverage was slow

in gaining a foothold. The first coffee mill was not built until 1833.

Kinds of Coffee.—Coffee belongs to the genus *Coffea*, which contains some 25 species, only three of which are of commercial importance.

Arabian coffee (*Coffea arabica*) is the source of 90 per cent of the world supply. The plant, a native of Abyssinia, is a beautiful shrub or small tree from 15 to 30 ft. in height. The smooth evergreen leaves are borne in pairs. The white, fragrant, star-like flowers (Fig. 215) are clustered in the leaf axils. The fruits, sometimes known as "cherries," are small fleshy berries, changing in color from green through yellow to red or crimson. The two greenish-grey seeds are covered with a thin membrane, the silver skin, and are enclosed in a dry husklike parchment. When only one seed develops, the fruit is known as a "pea berry," and commands a higher price. Coffee is distinctly a tropical crop and requires a hot moist climate. It is restricted to regions lying between 25°N.L. and 25°S.L. It needs at least 50 in. of rainfall, and prefers 75 to 120 in. A high humus content is also necessary. The plant is very susceptible to diseases. There are about 15 kinds of Arabian coffee under cultivation. One of them, Mocha coffee, a small-seeded variety grown in the Red Sea region, is highly esteemed.

Congo coffee (*Coffea robusta*) is a larger and more vigorous plant, with thick leaves. It bears heavily and is more hardy, and so is adapted to a wider range of climate. It is a native of the Congo region of Africa and is cultivated elsewhere. It constitutes about 85 per cent of the Java crop. The quality of Congo coffee is not so good as that of Arabian coffee.

Liberian coffee (*Coffea liberica*), a native of the west coast of Africa, is a still larger species, reaching a height of 40 to 50 ft., and with fruits 1 in. in diameter. The plant is more vigorous and less susceptible to disease. This coffee is used chiefly in blends, for the flavor and aroma are inferior.

Cultivation and Preparation of Coffee.—Coffee can be grown from sea level to an altitude of 6000 ft. and thrives best at the higher elevations. Under cultivation the plants are grown directly from seed, or seedlings are transplanted at 6-ft. intervals. Shading and constant weeding are essential, and catch crops are often grown. The plants begin to bear in the third year. The

best yield is obtained from the fifth year, and continues for about 30 years (Fig. 216).

The coffee berries are usually picked by hand when fully ripe, although in Arabia and parts of Brazil they are allowed to fall to the ground. After picking, coffee is prepared for the market by either the dry or the wet method. In the former the



FIG. 216.—A coffee tree in full bearing. (*Courtesy of the Arnold Arboretum.*)

berries are spread out on drying floors and exposed to the sun, care being taken to protect them from the rain. The berries are constantly stirred so they will be dried uniformly. Eventually the dried skin and pulp are cleaned off by machines and the parchment is removed by pounding in a mortar or by mechanical means. In the wet method the berries are run through a pulping machine, which removes the skin and part of the pulp. They are then placed in vats, where the remainder of the pulp

ferments and can be washed off. They are finally dried by the sun or artificial heat. The color of the finished product depends on the amount of moisture. After drying, the brittle parchment is cracked and removed by hulling machines, and the silver skin is rubbed off in polishing machines. The seeds or "coffee beans" are then graded and packed in burlap bags for shipment. Occasionally coffee is exported with the parchment still in place. Eventually the beans are roasted, a process which results in a loss in weight but a gain in bulk, and which is accompanied by many physiological changes. The aroma, flavor, and color develop during this process. No two varieties require the same amount of roasting, and there are many differences in the temperature used and the duration of the process. Before coffee is sold to the consumer it is usually ground. Trade coffee is often made up of different blends. The roasted coffee beans contain from 0.75 to 1.5 per cent caffeine, the stimulating principle, and a volatile oil, caffeol, which is responsible for the aroma and flavor. Glucose, dextrin, proteins, and a fatty oil are also present. The last tends to become rancid if coffee is kept too long.

Production and Consumption of Coffee.—The chief areas of coffee production have changed during the years. At first Arabia led, but was replaced in turn by the West Indies, Java, and Brazil. Ceylon was an important producer from 1830–1875 when the industry was destroyed by a blight. Today Brazil stands preeminent and produces over 70 per cent of the world's supply. Coffee is the principal crop and the chief source of revenue, and the economic structure of the country is dependent on the coffee trade. Brazil has suffered in recent years from overproduction and low prices, and has attempted to restrict the industry in all its phases, even using surplus beans as fuel. Colombia, the Dutch East Indies, Venezuela, Guatemala, Salvador, and Haiti are next to Brazil in importance. The growing of coffee is becoming increasingly prominent in the British possessions in Africa.

The United States leads in coffee consumption, using over half the world's supply. In 1935 the imports amounted to 1,755,809,167 lb., coming chiefly from Brazil and Colombia. The per capita consumption is estimated at from 11 to 13 lb. Other important coffee-using countries are Sweden with 15 lb. per

person, Cuba and Denmark with 13 lb., Belgium with 11 lb., and Norway with 10 lb. France uses about 7 lb. per person, Germany 4 lb., and the United Kingdom only 0.07 lb.

There are many ways of using coffee other than the familiar method in use in this country. In Turkey coffee grounds mixed with sugar are eaten, and Turkish coffee is a thick and syrupy concoction. In Sumatra coffee leaves are steeped and yield a wholesome and good-flavored beverage. Coffee extract and soluble coffee, as well as decaffeinized coffee, are also available. Coffee is often adulterated, usually with chicory, the roasted and ground roots of the chicory plant, already discussed. In Europe coffee containing chicory is preferred to the pure product. Substitutes for coffee are also in use, such as Postum and other cereal beverages, which are made from roasted barley or wheat, and which of course lack caffeine.

Tea

Tea is the most popular of the caffeine beverages, and it is used by fully one-half of the population of the world. It is prepared from the dried leaves of *Camellia sinensis*, a native of Assam in India or of China. Tea has been associated with the latter country since early times. At first it was valued only for its medicinal properties, but since the fifth century it has served as the principal beverage. The word "tea" comes from "te," which is used in one of the Chinese dialects in place of the more universal "cha." Tea was introduced into Japan about 1000 A.D. It was known in Europe in the sixteenth century, but did not become important until the seventeenth. Great Britain today is the chief consumer of tea, and London is the great tea market of the world. The prominence of the tea-drinking habit in England, however, has come about during the last 100 years.

Cultivation of Tea.—The tea plant in nature is a small tree, but it is grown under cultivation as a shrub, 3 or 4 ft. in height (Fig. 217). The leathery lanceolate leaves have a serrated margin and numerous oil glands. The white or pinkish flowers (Fig. 218) are produced in the axils of the leaves, and are followed by capsular fruits. Constant pruning stimulates the vigorous development of new shoots, and these "flushes," as they are known, are the source of the commercial product.

Tea is a crop of tropical and hot temperate regions. The nature of the plant and the methods of cultivation vary in different localities. Some 1000 varieties are known. The tea plant is propagated from seed or seedlings. The yield may be anywhere from 200 to 1000 lb. per acre, and continues for 50 years or more. There are records in Japan of a single plant living for two centuries. Tea can be grown from sea level to an altitude of 5000 ft. Often steep slopes and soil that is too poor for other types of agriculture are used. In China the tea is



FIG. 217.—The tea plant (*Camellia sinensis*) under cultivation in Japan. The small shrub is often planted in hedges.

grown on small farms, and is prepared for the market by primitive methods. In Ceylon, on the other hand, tea is cultivated on large plantations, and the most modern mechanical methods are used in its preparation.

The tea leaves are picked by hand or with scissors, and an expert can pick from 25 to 75 lb. a day. In China, where growth stops during the winter months, only three or four pickings a year are possible. In the hotter areas, such as Ceylon, where growth continues throughout the year, as many as 25 or 30 pickings can be made. The grade of tea depends on the age of the leaves. In *golden tips* the youngest bud only is used; in *orange pekoe* the smallest leaf; in *pekoe* the second leaf; in *pekoe-souchong* the third leaf; in *souchong* the fourth leaf; and in

congou the fifth and largest leaf to be gathered. The flavor and quality vary with the soil, climate, age of the leaf, time of picking, and method of preparation.

Preparation of Tea.—The process of preparing tea from the fresh leaves in general is as follows: The leaves are first exposed to the sun or heated in shallow trays, until they become soft and



FIG. 218.—Glass model of the tea plant, showing the habit of growth, flowers, and flushes. (*Courtesy of the Botanical Museum of Harvard University.*)

pliable. They are then rolled, by hand or by machine. This curls the leaves and removes some of the sap. Finally the curled and twisted leaves are completely dried in the sun, over fires, or in a current of hot air. In the final product, known as *green* tea, the dried leaves are dull green with an even texture and quality. In making *black* tea, the leaves are fermented after rolling by covering them up and keeping them warm. This

causes them to lose their green color and changes their flavor. After fermentation, the leaves are dried in the usual manner. China produces both green and black tea, Japan mostly green, and India and Ceylon chiefly black. In Formosa the so-called *oolong* tea is produced. This is only partially fermented and is intermediate between black and green, with the color of the former and the flavor of the latter. The various pekoes, souchongs, and congous are black teas, while *gunpowder* and *hyson* are the most important grades of green tea.

Scented teas are prepared by drying the leaves with fragrant flowers, such as jasmine, and then sifting out the dried flowers. Brick tea is made by steaming the coarser leaves, twigs, and even dust for a few minutes and then pressing them into molds, sometimes with the addition of a little rice paste. Brick tea is exported from China to Russia and Tibet. Where tea is grown on large plantations and prepared in factories, it can be packed at once for export. In China and Japan where enormous quantities are prepared by hand labor on small farms, the tea has to be thoroughly redried by the exporters before shipment. Tea is usually shipped in light boxes lined with lead or zinc to protect the tea from air and moisture, or in small packages lined with metal foil. The tea that finally reaches the consumer is usually a blend of several different varieties. Blending is a very delicate operation and can be done only by an expert.

Tea contains from 2 to 5 per cent theine, an alkaloid identical with caffeine, together with a volatile oil and considerable tannin (13 to 18 per cent). When an infusion is made with hot water, the alkaloid and the oil readily dissolve out and the resulting beverage has a stimulating effect and a characteristic taste and aroma. If the leaves are steeped for a longer period, the tannin dissolves and the liquid becomes bitter and loses its beneficial qualities.

Production and Consumption of Tea.—For hundreds of years all the tea came from China. Java began to export in 1826, India in 1830, Formosa in 1860, and Ceylon in 1890. Today China produces nearly one-half (48.9 per cent) of the world's tea, while India and Ceylon supply about 22 per cent and 13 per cent, respectively. India and Ceylon, however, are responsible for one-half the world's tea exports, followed by the Dutch East Indies, China, Japan, and Formosa. Tea growing has been

experimented with in the West Indies, and even in the Carolinas and other Southern states. The crop, however, does not thrive in this country, and there is not enough cheap labor available to make the industry a financial success. Great Britain is the great consumer of tea, importing five times as much as any other country. The United States is second, followed by Australia, Russia, Canada, and Holland. Chinese and Japanese teas are more important in the United States, while Great Britain is the chief consumer of the Indian and Ceylon teas. Java supplies Europe and Australia. The per capita consumption in England is estimated at 9.8 lb., and in the United States only 0.077 lb. The imports of tea into the United States in 1935 amounted to 86,234,659 lb.

Cocoa and Chocolate

Cocoa and chocolate are prepared from the seeds of the cacao or cocoa tree (*Theobroma Cacao*), a native of the highlands of tropical America. The cultivation and use of cocoa are so ancient that it is improbable that any wild trees exist today. Cocoa is grown throughout tropical South and Central America, in the West Indies, and in many other parts of the world. The use of cocoa and chocolate by other than the native peoples is of recent origin as compared with the use of tea and coffee. The beverage was unknown to Europeans until the voyage of Cortez in 1519, and was not introduced into Europe until 1526. Chocolate was the chief drink of the Aztecs and other native American peoples. Since its introduction to the Northern races, cocoa has steadily increased in popularity; today the original regions of cultivation are insufficient to supply the demand, and new areas have been developed in other countries.

Cultivation of Cocoa.—Cocoa is distinctly a tropical crop and is grown within 20° of the equator. It also requires special environmental conditions. It is sensitive to drought and wind, and so needs shelter from the direct rays of the sun and protection from strong winds. Catch crops and permanent shade trees are usually grown with cocoa. A deep rich alluvial soil with abundant moisture and suitable drainage is also necessary. Cocoa cannot be grown at altitudes above 2500 ft., and it is injured by temperatures below 60°F. The crop is raised from seed or

transplanted seedlings with the individual plants in rows at 4- or 5-ft. intervals.

The cocoa tree is rather small, from 15 to 40 ft. in height, with numerous branches. The shiny leaves are ovate in outline and often 1 ft. in length. The flowers and fruits are borne on short

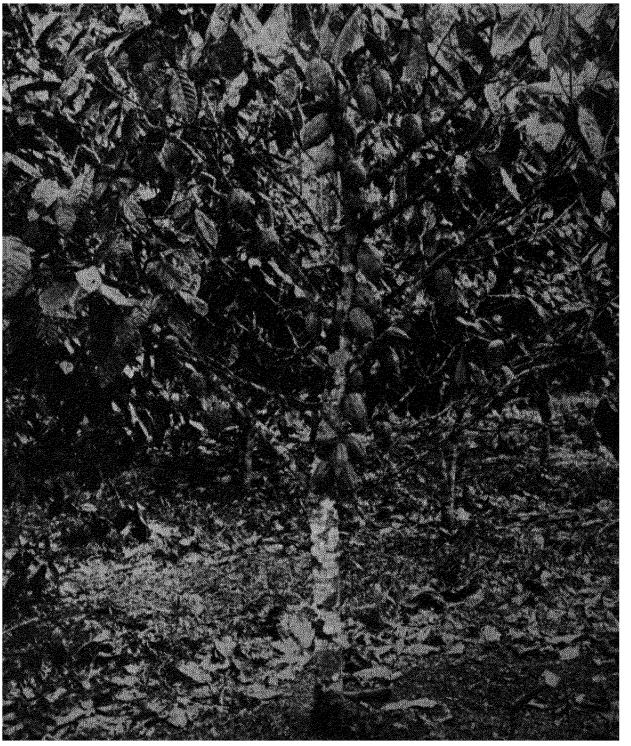


FIG. 219.—A cacao tree (*Theobroma Cacao*) in fruit. Note the pods attached directly to the trunk and larger branches.

stalks directly on the trunk and larger branches (Fig. 219). The trees begin to bear when four or five years of age, and reach full-bearing during the ages of 12 to 50 years. The plants produce flowers and fruit throughout the year so that several crops annually are possible. The fruits are podlike capsules 6 to 9 in. long and 3 or 4 in. thick, with tapering ends. They contain a mucilaginous pulp and from 40 to 60 or more seeds

(Fig. 220). The fruits ripen in about four months, the color changing from green to a reddish purple or yellow. Dried specimens are often chestnut brown in color.

Kinds of Cocoa.—Numerous varieties of cocoa are cultivated. The most important of these are the Criollo and Forastero. In the Criollo type the fruit is soft and thin skinned, with a rough surface and pointed ends. The seeds are plump, pale in color, and whitish within. The Forastero varieties have hard, thick-shelled pods with seeds of a pale to deep-purple color.

Preparation of Cocoa and Chocolate.—In preparing the seeds or cocoa beans for market, the pods are carefully gathered by

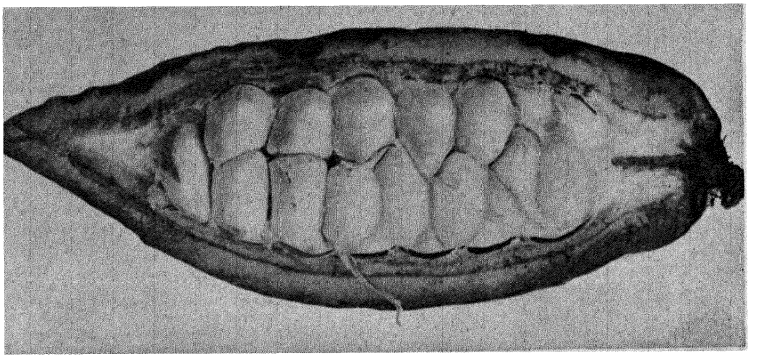


FIG. 220.—Section of a cocoa pod showing the seeds or "beans" imbedded in the mucilaginous pulp.

hand and cut open with a knife. The pulp and seeds are then scooped out, cured, and usually fermented. Occasionally they are merely dried in the sun, but they are more desirable if fermentation takes place. This process may be carried on by piling the seeds in heaps for several days and then spreading them out to dry. Usually specially constructed vats or houses are used, which afford protection from rain and allow the liquids from the disintegrating pulp to run off. The beans in these "sweating boxes" are constantly stirred. During the fermentation process, which lasts about a week, the beans become brownish red in color, lose their bitter taste, and develop an aroma. They are then washed and dried, and polished by machines or the feet of the natives to remove any of the dry pulp.

Commercial cocoa and chocolate are prepared from the beans in European and American factories. The beans are first cleaned to remove any impurities and are then sorted. They are next roasted at a temperature from 257° to 284°F. in iron drums. This develops the flavor, increases the fat and protein content, and decreases the amount of tannin. The shells become dry and brittle and the seeds easier to grind. The beans are now passed between corrugated rollers which break the shells into small fragments. These are removed in a winnowing machine. The seeds or "nibs" are finally ground to an oily paste, constituting the "liquor" or bitter chocolate, which is the starting point for further operations.

When cooled and hardened, this material is the bitter chocolate of commerce. Sweet chocolate is made by adding sugar and various spices or other aromatic materials. Milk chocolate contains milk as well as sugar and spices. Cocoa is prepared by removing about two-thirds of the fatty oil in hydraulic presses and powdering the residue.

The fatty oil present is cocoa butter, the uses of which have already been discussed. The cocoa shells are used for beverage purposes, for adulterating cocoa and chocolate, for fertilizer, and for cattle feed.

Production and Consumption of Cocoa.—British West Africa now leads in the production of cocoa with about 64 per cent of the total output. The Gold Coast, Nigeria, and St. Thomas are the leading countries. South America produces about 34 per cent, chiefly in Brazil. Ecuador, Venezuela, Trinidad, and the Dominican Republic also grow large amounts. Asia and the South Seas produce only a little over 1 per cent.

The United States is the chief consumer of cocoa, with a per capita consumption of over 3 lb. In 1935 imports amounted to 606,310,791 lb. of cocoa beans, 3,051,571 lb. of prepared cocoa, and 302,141 lb. of prepared chocolate. Germany, Holland, and Great Britain are other large users of cocoa.

Cocoa is in a class by itself as a beverage, since it is also a food. The seeds contain less than 1 per cent of an alkaloid, theobromine, which, with a few traces of caffeine, is responsible for the stimulating properties. They also contain 30 to 50 per cent of a fatty oil, 15 per cent starch, and 15 per cent protein. A volatile oil develops during the roasting process.

Maté

Maté, yerba maté, or Paraguay tea, as it is variously known, is next to coffee, tea, and cocoa in importance. It is obtained from the leaves of various species of holly, chiefly *Ilex paraguariensis*. These plants grow wild in southern Brazil, Paraguay, and Argentina, and they are also cultivated to a considerable extent. The use of maté in South America goes back to antiquity. Originating with the natives, it was adopted by the first white colonists and today is the universal beverage. The plant is an evergreen shrub or small tree (Fig. 221). The oval leaves are from 4 to 5 in. in length, with serrated margins, and



FIG. 221.—A three-year old plant of the Paraguay tea (*Ilex paraguariensis*). Maté, the universal beverage of millions of South Americans, is obtained from the leaves of this plant. (*Courtesy of the United Fruit Company.*)

resemble tea leaves. Maté can readily be grown from seed and the first crop is ready within a year, although the best yield is obtained from older plants.

Large leafy branches are cut and dried over fires. They are then beaten with sticks to break off the leaves, which are broken up further and ground to a coarse powder. The leaves contain up to 0.5 per cent of theine, a volatile oil, and some tannin. Maté has an agreeable aroma and slightly bitter taste, though



FIG. 222.—A native collecting the fruits of *Paullinia Cupana* in Brazil. The seeds are the source of guarana, the most stimulating of the caffeine beverages.

it is much less astringent than tea. It has valuable restorative and stimulating properties. The beverage is usually prepared in a gourd or cup by pouring boiling water on the leaves, often with sugar and lemon. It is then sucked through a *bombilla*, a hollow tube of silver, brass, or straw with a perforated bowl, which acts as a strainer. Maté is the universal drink of 15,000,000 South Americans, and is increasing in popularity in the United States. It is also used somewhat in the preparation of soft drinks. In 1935, 422,149 lb. were imported.

Guarana

Guarana is the most stimulating of all the caffeine beverages, as it has three times as much caffeine as coffee. It is prepared from the seeds of *Paullinia Cupana*, a large woody climber of the

Amazon valley. The natives grind up the seeds with water and cassava flour and mold the resulting paste into brown sausage-shaped cylinders or other forms. These are dried in smoke, becoming hard as stone. They will keep for many years. For use it is grated and added to either hot or cold water. One-half a teaspoonful of this reddish-brown guarana in a cupful of water is equivalent to two or three cups of strong coffee. Guarana contains some tannin and a volatile oil and is bitter and astringent with a bitter-sweet taste. The beverage is extensively used in Brazil, where the plant is cultivated to some extent (Fig. 222). Under such conditions it is a small bush.

Khat

The dark-green leaves of *Catha edulis* are used in Arabia to yield khat, the principal beverage of the natives. This shrub (Fig. 223), which resembles tea, was grown in terraced gardens in Arabia long before coffee was introduced, and may even antedate tea. It grows wild in Abyssinia, and is cultivated in other parts of Northeastern Africa. The leaves and buds contain an alkaloid similar to caffeine, and are used dried or are chewed in the fresh condition for the stimulating effect. Khat is an excellent beverage plant and is worthy of exploitation.

Cola

Cola nuts (Fig. 123), the seeds of *Cola nitida*, already discussed under masticatories, are also used in Africa and elsewhere for beverage purposes. The drink is prepared by powdering the seeds when needed and boiling some of the powder in water for a few minutes. Cola contains 2 per cent caffeine, as well as other ingredients, and so is very invigorating. The seeds are imported into the United States for use in various soft drinks, principally Coca-Cola.

Cassine

Cassine is a tealike beverage obtained from two species of holly, *Ilex Cassine* and *I. vomitoria.* These plants are tall compact shrubs or small trees with small, oval, evergreen leaves and tough branches. They occur on the sandy soils of the coastal plain from Virginia to Mexico and are often found in dense thickets. The Indians of this region were the first to use

cassine for beverage purposes. They prepared an infusion of fresh or dried leaves which was known as yaupon or black drink. This was used medicinally as a spring tonic and emetic, and also played an important part in religious rites. It was sometimes fermented. Although the use of cassine was first reported from



FIG. 223.—The leaves and flowers of *Catha edulis*. Khat, the principal beverage of the Arabians, is obtained from the leaves.

Florida as early as 1562, and was practiced to some extent by the early settlers, it never became very popular. Recently attention has been directed to the beverage as a basis for soft drinks. The leaves and shoots are picked and dried in the sun on trays or are roasted in ovens. Twigs and older leaves are sometimes steamed, dried, and ground. Cassine is prepared by boiling or making an infusion. The beverage is dark colored

with a very sharp, bitter taste and tealike odor. It contains caffeine, tannin, and essential oils.

OTHER NONALCOHOLIC BEVERAGES

Ordinary beverages that do not contain alcohol are commonly referred to as *soft drinks*. These include a great variety of preparations, only a few of which can be discussed.

Fruit juices are the simplest kind of soft drinks, consisting of the extracted juice alone, or with sugar and water added. Although fresh juice is readily obtainable, synthetic flavors have been all too common in commercial products. The most familiar types of fruit juices are lemonade, orangeade, and similar beverages. Orange juice, tomato juice, and pineapple juice are popular. Shrubs and sherbets made from strawberries, raspberries, etc., were more in vogue at an earlier time. Grape juice is made by expressing the fresh fruit and heating the liquid to extract the color and to pasteurize it and thus prevent fermentation. Sweet cider, the expressed juice of apples, and perry, obtained from pears, are well-known. These juices contain wild yeasts and will ferment after 24 hours or so unless they are pasteurized, or treated with benzoate of soda or other chemicals to kill the yeast organisms.

Soda water to the average person in this country means the familiar beverage dispensed at soda fountains. This is one of the most typical soft drinks in the United States, but its use is almost entirely restricted to this country. Today, in spite of its name, the beverage contains no soda, but consists of water charged with carbon dioxide and mixed with a syrup composed of sugar and various natural or artificial flavoring substances. Bottled soda, commonly known as pop, is also important.

An enormous number of bottled soft drinks are available in this country, chief among which are malt beverages, ginger ale, sarsaparilla, and Coca-Cola. The **malt beverages** are made from malted barley, or other grains, before fermentation has started or progressed very far. They include the "near beers," which have an alcoholic content of less than 0.5 per cent. **Ginger ale** consists of acidulated sugar, water, and carbon dioxide, flavored with ginger and capsicum. **Sarsaparilla** is similar, but the flavor is due to sarsaparilla, wintergreen, and other aromatics. **Coca-Cola** has had a long and interesting history. Originally

it was used for medicinal purposes and was obtainable only by prescription. Its components included coca leaves, which contained some cocaine, and cola nuts, with a high caffeine content. As its stimulating properties became known, it gradually came into use as a beverage, and in recent years it has been prepared on a larger and larger scale for general consumption. However, its use as a beverage necessitated considerable change in the contents. Today only dried coca leaves, from which all traces of active principles have been removed, are used, while the amount of cola has been reduced so that the caffeine content of a glass of Coca-Cola is about that of a cup of coffee.

ALCOHOLIC BEVERAGES

The use, and the abuse, of alcoholic beverages have paralleled the entire history of mankind. From earliest time it has been all too easy for man to observe the natural process of fermentation, and to use its products for his own pleasure. In all ages and at all times man has resorted to alcohol. Today the consumption of alcoholic beverages of some sort is world wide, existing in both primitive and civilized countries. Alcohol is a poison, and, when taken to excess, produces very deleterious effects on the human system. The various inebriating beverages bring about cerebral excitation, followed by depression, and may lead to the complete, though temporary, suppression of the functions. The evils of excessive drinking and chronic alcoholism are perfectly obvious to everyone. As regards the moderate use of alcohol, it is not within the province of this book to discuss the relative merits of the question. Strong arguments are produced by believers in prohibition or total abstinence, and on the other hand by those who favor moderate indulgence. It is clear, however, that in any work which purports to treat of useful plants and plant products there should be some discussion of the alcoholic beverages that play so important a part in man's life.

Alcoholic beverages fall naturally into two classes: the fermented beverages, in which the alcohol is formed by the fermentation of sugar present either naturally in the source or produced by the transformation of starch; and the distilled beverages, which are obtained by the distillation of some alcoholic liquor.

Fermented Beverages

Wine

Wine is the most important and also the oldest of the fermented beverages. It was known in remotest time, and its antiquity is evidenced by the fact that the word for wine is the same in many languages. Wine is produced by the conversion of sugar, which occurs in fruits or other parts of plants, into alcohol and carbon dioxide. This process of alcoholic fermentation is brought about through the agency of wild yeasts which are present on the skins of the fruit. Unless some specific fruit is mentioned as the source, wine is always understood to mean the fermented juice of the grape.

The cultivation of grapes for wine making has been carried on for centuries in many parts of the world. Today the industry is most prominent in Southern and Central Europe, although the United States, Australia, and South America have extensive vineyards. The wine grape (*Vitis vinifera*) and its varieties are the principal source. Successful grape growing is not a haphazard business, and a knowledge of the best environmental conditions and many other factors are essential. Wine making is also an art that requires great skill and experience. The finest grades are produced in the older vine-growing countries, which have years of experience behind them.

Wines vary considerably in their characteristics. The alcoholic content varies from 7 to 16 per cent. It is impossible to produce a wine naturally with a higher content, for the yeast plant is killed under such conditions and further fermentation is prevented. The sugar content of the grapes is from 12 to 18 per cent. Fermentation of the fruits or the juice is carried on in vats. The optimum temperature is 68°F. The agreeable aroma and flavor are due to various aromatic principles present in the fruit. The characteristic bouquet develops only after the wine has been aged for periods varying from four or five years to several decades.

Red wines are made from grapes with colored skins and derive their own color from the pigments and other substances present in the skins. White wines are made from white grapes, or expressed juice. In the so-called dry wines or sour wines, the

sugar is almost completely fermented. In sweet wines, on the other hand, fermentation is stopped before all the sugar is converted, and at least 1 per cent is still present. In sparkling wines, the wine is bottled before fermentation is complete so that carbon dioxide is produced within the bottle. Fortified wines have a higher alcoholic content, due to the addition of wine, brandy, or alcohol.

PRINCIPAL WINES AND WINE-GROWING COUNTRIES

France.—France is the chief wine-producing country of the world, with over 4,000,000 acres devoted to vineyards. The industry, however, is more or less localized. The region around Bordeaux in the valleys of the Garonne and Gironde produces most of the wine. This district is the most outstanding single wine-growing area in the world and is famous not only for the quantity but for the quality of its output. Here are the most famous vineyards and here are produced the finest wines in great variety. Among these are the Medocs, renowned red wines or clarets; Graves, dry wines with both red and white varieties; and the white sauternes and Barsacs, which are sweeter and richer. The Bordeaux wines include regional wines, which consist of blends from several vineyards, as well as the finest grades that are bottled by individual châteaux and bear their names.

Burgundy wines are produced in the hilly country of the Côte d'Or in east central France. These red and white wines are drier and have more body and flavor than the Bordeaux wines. Both still and sparkling wines are made.

Champagnes are produced in the vicinity of Reims and Epernay. Only wines made in this Champagne region have a right to the name. Black and red grapes are used and the manufacture involves a series of elaborate processes which extend over a period of six or seven years. Because of the popularity of these sparkling wines there are many imitations, made by charging light wines with carbon dioxide.

Other noteworthy French wines are produced in the valleys of the Loire and Rhone and in Alsace and Touraine.

Germany.—The Rhine valley has long been famous for its vineyards and every foot of available ground on the hillsides is devoted to grapes. The Rhine wines, sometimes called hock,

are light colored with a rich flavor and fine bouquet. Other similar wines are produced in the valleys of the Moselle, Neckar, and Main.

Italy.—Chianti, Asti, and other Italian wines have long been known, even prior to the days of Horace who sang the praises of Falernian wine. Although today Italy ranks second to France in wine production, only a few of its products are world famous. The chief wine-producing regions are Piedmont, Tuscany, and

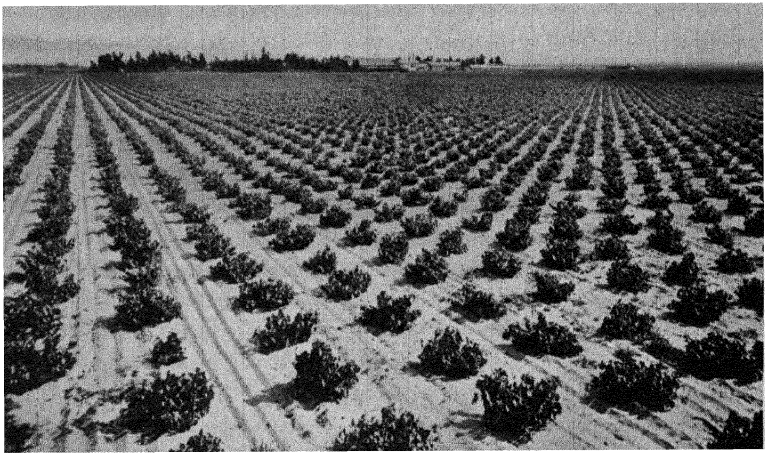


FIG. 224.—Vineyards in the San Bernardino Desert, California. (*Reproduced from U.S.D.A. Farmers' Bulletin* 1689, *Grape Districts and Varieties in the United States.*)

the country from Naples southward. Sicily is noted for its Marsala, a sherry-like fortified wine.

Hungary.—Hungary is the home of Tokay, a golden-yellow wine with a sweet rich flavor and rare bouquet. It is more of a liqueur than a wine as it has a soft oily taste. Tokay is expensive and the supply is limited. There are many cheap imitations and adulterations.

Spain.—Spain is noted for the production of sherry, a dry wine, usually fortified with brandy, and having an alcoholic content of 15 to 24 per cent. Commercial sherries are all blended and several different grades are on the market. Malaga, another Spanish wine, is rich and sweet.

Portugal.—The chief wine of Portugal is port, which is heavy and sweet, owing to the presence of considerable unfermented

sugar. New port is deep purplish red in color. Wine that has been aged in casks loses some of its color and takes on a tawny hue. Port is often blended and fortified and is frequently adulterated.

Madeira.—Madeira is a fortified white wine made from grapes grown on the island of Madeira. Its quality is improved by heat and shaking, and so it is stirred in glass-lined tanks and then heated. Formerly the wine was shipped on long sea voyages which produced the desired result.

United States.—Grapes grown in the United States yield a wine of a distinctive type and general all-round excellence. The domestic wines do not need foreign names for they are just as good as most European wines and have received high awards at various foreign expositions. The principal wine-producing states are California (Fig. 224), New York, Ohio, and Virginia. The first three specialize in white wines, while Virginia is noted for its red wines.

Beer

The art of brewing alcoholic beverages from cereals is very old. Millet was probably the first cereal to be so used, and it is still fermented in India and parts of Africa. Rice, maize, and rye have been used to some extent, but barley has always been the chief source. Barley "wine" was known to the ancient Egyptians and Romans. Beer was popular during the Middle Ages. For a long time the monasteries were the chief source of supply. As early as the thirteenth century beer was a favorite beverage in England. It was home brewed for the most part and was a dark muddy liquid with a high alcoholic content. Early in the nineteenth century the lighter German beers began to replace it in popularity. The commercial manufacture of beer involves two distinct processes, malting and brewing.

Malting.—Malting has as its object the conversion of the starch present in the grains into sugar. This is brought about through the agency of an enzyme, diastase, which is produced during the process of germination. Barley is used almost universally for malting. Occasionally some maize is added. Only large, fresh, perfect, light-colored grains are used, which are free from chaff and other impurities. The barley is first steeped in water for from one to four days. During this time the grains

absorb their own weight of the water. The grains are then placed in heaps or layers 6 in. deep until germination starts. Next they are spread out on the malting floor in a temperature of 50 to 60°F., and are constantly turned over. When the requisite amount of germination has occurred, the shoots are about one-third the length of the grain. The germinated barley is then kiln dried for 12 hours. This prevents any further germination and consequent loss of sugar. The color of the dried product, which is known as malt, is dependent on the degree of heat.

Brewing.—The malt is crushed or coarsely ground in a roller mill and is mixed with water heated to 170°F. In some cases unmalted cereals are added. The sugar dissolves out and the infusion or wort is drawn off. This process of mashing is repeated several times. The residue is fed to cattle. The wort is then boiled with hops for 2 hours. The hops impart the bitter flavor and tonic properties and improve the keeping qualities by preventing bacterial action. The liquid is then cooled rapidly and yeast is added to bring about the fermentation of the sugar. Care must be taken to keep an optimum temperature for enzyme action and to prevent the process from continuing too long, in which case acetic acid might be formed. It is usually stopped before fermentation is complete and the yeast is removed. The beer is then drained off and strained and allowed to cool in casks. A slow fermentation continues, increasing the alcoholic content and forming the carbon dioxide that is responsible for the foaming of the beer. Beer contains from 3 to 8 per cent of alcohol. Its nutritive properties are due to the presence of sugar, dextrin, and various proteins and phosphates.

Kinds of Beer.—Differences in temperature during the brewing process are responsible for the heavy and the light beers. *Lager beer* is a term which should be restricted to beer that has been aged for some time. *Bock beer* is a very strong dark beer, usually made in the spring from the first of the new malt and hops. The German *weiz bier* does not contain hops.

Ale originally meant any kind of malt beverage, and this usage continued until hops began to be used. Today the difference between beer and ale is due to differences in the temperature during fermentation. Ale is brewed by "top fermentation" at higher temperatures, around 58°F., while beer is brewed by "bottom fermentation" with temperatures

averaging 40°F. The alcoholic content of ale is 4 to 7 per cent, while that of beer is 3 to 5 per cent.

Porter, first brewed in 1722, is a dark-brown beer with a slightly burned taste. It is made from inferior grades of malt. The color is sometimes heightened by the addition of caramel or licorice. Porter is stored for six to eight weeks before it is used. *Stout* is a similar beverage, but much heavier. It is stored for at least a year before it is used.

Beer is usually made from pale or amber-colored malt, ale from brown, and porter and stout from black malt.

Other Fermented Beverages

Only a few of the countless other fermented beverages can be discussed. Most of them are used locally and are of minor importance.

Hard Cider.—The fresh juice of apples begins to ferment within 24 hours and gradually increases in alcoholic content until the stage known as hard cider is reached. While the domestic production of hard cider may be used for beverage purposes, a considerable proportion is allowed to undergo acetic acid fermentation and become vinegar. Cider and other fruit vinegars are also made on a commercial scale. Pear juice, or perry, is likewise often fermented.

Root Beer.—Root beer consists of an infusion of various roots, barks, and herbs, among them sarsaparilla, ginger, and wintergreen, with the addition of sugar and yeast. Fermentation sets in and the beverage becomes charged with carbon dioxide. Root beer may also consist of an alcoholic extract of various aromatics and bitters. Nonalcoholic root beer is also made. *Spruce beer*, a diffusion of the leaves and twigs of the spruce, and *birch beer*, obtained from the bark of the black birch, are similar in nature.

Mead.—Mead is a fermented beverage of great antiquity and it is still used in Africa and to some extent elsewhere. It is fermented from honey and water and has a winelike flavor. Mead was introduced into England by the Scandinavians, and the beverage played an important part in the nuptial ceremonies of the latter people which lasted for 30 days. Because of this fact, the duration of these ceremonies was commonly known as the honeymoon.

Sake.—This important beverage of Japan and China is prepared by fermenting rice. No hops are used. Sake contains more alcohol than beer or wine. It has been used for 2600 years, with records as far back as 90 B.C.

Palm Wine.—The fermented juice obtained from the inflorescences of many varieties of palms is another beverage of great antiquity. The sugary exudation has been referred to previously as a source of sugar. Palm wine or toddy was known to Herodotus as early as 420 B.C. It has been prepared by the natives of tropical regions of both hemispheres. The most important species utilized are *Raphia vinifera, Elaeis guineensis, Borassus flabellifer, Arenga pinnata, Phoenix dactylifera,* and *Cocos nucifera.* When palm wine is distilled, it yields arrack.

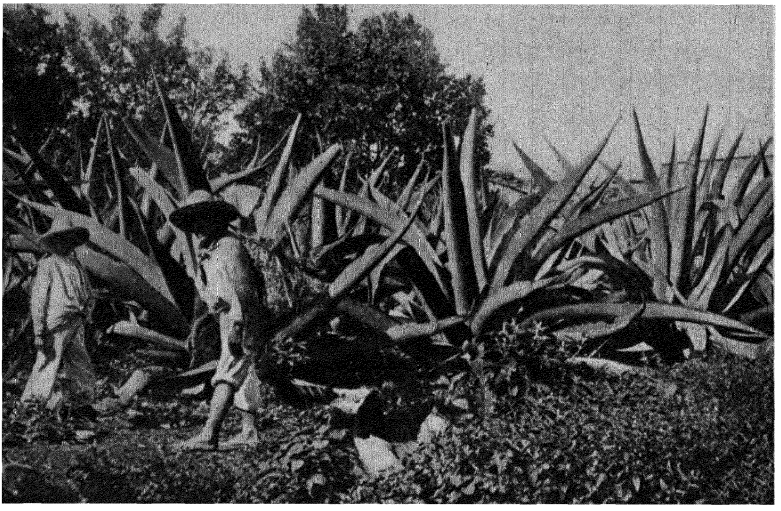


FIG. 225.—Maguey or pulque plants (*Agave* sp.) under cultivation in Mexico.

Pulque.—The fermented juice of the maguey (*Agave atrovirens*) and other agaves (Fig. 225) was early used in Mexico as a beverage. The juice is obtained by making incisions in the flower stalk. It is often distilled, and constitutes mescal.

Other plants whose juices are fermented for use as a beverage include the banana, sugar cane, yucca, sorghum, cassava, algaroba, and cactus.

Distilled Beverages

Whisky

Whisky is distilled from a fermented mash of malted or unmalted cereals or potatoes. After several distillations of the mash a product known as "low wines" results. Further distillations yield the "high wines." A mixture of high wines and water constitutes straight whisky. At first this is harsh and unpalatable, owing to the presence of from 20 to 40 volatile principles, such as fusel oil and various ethers and aldehydes. It must be aged to allow these principles to disappear. The finest bonded whiskies are aged in charred oak containers for at least four years and often much longer. Whisky is colorless at first, the color developing during the aging process. Whisky that contains 50 per cent alcohol by volume is known as 100 proof. Similarly that which contains 45 per cent alcohol is 90 proof. A continued distillation of the high wines finally results in the neutralization or elimination of all the volatile substances and yields the so-called neutral spirits. These are used in blended whiskies, in making cordials, and for other purposes. They are made from corn in the United States and from potatoes in Germany.

American straight whiskies are made from maize or rye, the former constituting the famous "corn" or moonshine of the South. Bourbon, originally made only in Kentucky, is made from a mixture of maize, rye, and malt. Canadian Club is a blend of various straight whiskies with neutral spirits.

In the preparation of Scotch whisky only barley malt is used. The characteristic flavor is due to the smoke of the peat fires that are used in drying the malt. Irish whisky is made from malt, or a mixture of malt and unmalted grains of barley, oats, and maize. Vodka is the Russian equivalent of whisky.

Brandy

In a strict sense brandy is distilled only from wine, although the term is also applied to a distillation of the fermented juice of various fruits. The finest brandy is made in France in the Charente district. This product alone has the right to be called cognac. Other French brandies are known as armagnac or

eau de vie. The best grades are made from white wines. Brandy is a clear colorless liquid and stays so when kept in glass. The brown color develops when it is stored in casks. Brandy is often artificially colored with caramel. The alcoholic content is high, amounting to 65 or 70 per cent.

Among the fruit brandies may be mentioned apricot, peach, and blackberry brandy. These are often used as cordials. Apple brandy is known commonly as applejack.

Rum

Rum is distilled from various unrefined products of the sugar cane, chiefly the juice and molasses. It is one of the oldest and most widely known of the distilled beverages. The flavor and aroma, which are due to various aromatic substances, improve with aging. The color is often due to caramel. Rum played an important part in the economic and social life of the American colonies from 1687, particularly in New England, where many distilleries were located. Considerable rum is distilled today in the West Indies, chiefly in Jamaica, St. Croix, and Demerara. Rum contains about 40 per cent alcohol.

Gin

Gin is distilled from a fermented mash of malt or raw grain. The best grades are obtained from barley malt and rye. Several distillations are necessary. Gin was invented in Holland and that country still produces the best grade, although England is a close second. The flavor of gin and any medicinal value that it may possess are due to oil of juniper. Other aromatic essential oils may be used for flavoring, as in the case of sloe gin and orange gin. Gin has many substitutes and imitations, made chiefly by adding essential oils to grain alcohol.

Liqueurs and Cordials

The various liqueurs and cordials consist of sugar and alcohol flavored with various essential oils. They may be prepared by the addition of the flavoring material to neutral spirits or brandy or by the distillation of fermented fruits. The majority contain no harmful substances other than alcohol. Others, as in the case of absinthe, already discussed, do have deleterious principles and their use is forbidden in most countries.

Liqueurs often consist of various oils and cordials carefully blended according to secret formulas. French monasteries have long been famous for the manufacture of liqueurs. *Benedictine* has been made since 665 A.D. and has been a commercial product since 1792. *Chartreuse* is also made by monks. *Maraschino* is distilled from bruised marasca cherries grown in Dalmatia, sweetened and flavored with cordials. *Curaçao* is distilled from the dried rind of bitter oranges steeped in alcohol and water, with the later addition of sugar and rum. *Kirschwasser*, or black-cherry brandy, is distilled from the fruits, and sugar and alcohol are added.

Essential oils used in the preparation of liqueurs include anise and coriander (anisette), caraway (kummel), peppermint (créme de menthe), bitter almonds (créme de noyau), and clove.

Aperitifs and Bitters

Many alcoholic preparations are used for their appetizing and tonic effects. *Vermouth*, the best known of the **aperitifs,** is a light bitter wine slightly fortified and sweetened and flavored with gentian, wormwood, and other herbs. It is made chiefly in France and Italy. French Vermouth is dry, while Italian Vermouth is either sweet or dry.

Bitters are prepared by steeping various herbs with bitter principles in water or alcohol. After the principles have dissolved out, the infusion is strained and alcohol is added to prevent decomposition. *Angostura bitters*, which contains quinine and several aromatics, and *orange bitters* are typical of this group.

SYSTEMATIC LIST OF SPECIES DISCUSSED

THALLOPHYTA

Algae

Alaria esculenta (L.) Grev. Murlins
Chondrus crispus (L.) Stackh. Irish moss
Eucheuma spinosum (L.) J. Agardh. Agar-agar
Gelidium corneum Lam. Agar-agar
Gracilaria lichenoides (L.) Harvey. Agar-agar
Macrocystis pyrifera (L.) C. Agardh. Kelp
Porphyra laciniata (Lightf.) Ag. Pink laver
Rhodymenia palmata (L.) Grev. Dulse
Ulva lactuca (L.) LeJol. Green laver. Sea lettuce

Fungi

Agaricus campestris L. (*Psalliota campestris* (L.) Fr.) Meadow mushroom
Amanita muscaria (L.) Pers. ex Fr. Fly agaric
Claviceps purpurea (Fr.) Tul. Ergot
Cortinellus Berkeleyanus Ita & Imar. Shii-take
Morchella esculenta L. Morel
Tuber aestivum Vitt. Truffle
Tuber brumale Gronof. Truffle
Tuber melanosporum Vitt. Truffle

Lichens

Evernia furfuracea (L.) Ach. Oak moss
Evernia prunastri (L.) Ach. Oak moss
Ramelina calicaris Ronl.
Roccella tinctoria D.C. Archil. Cudbear

* PTERIDOPHYTA

Dryopteris Filix-Mas (L.) Schott. Male fern

SPERMATOPHYTA

Gymnospermae

Cycadaceae

Cycas circinalis L.
Zamia floridana A.D.C.

Taxaceae

Dacrydium cupressinum Sol. New Zealand red pine
Phyllocladus trichomanoides D. Don. Celery pine
Podocarpus dacrydioides A. Rich. New Zealand pine
Podocarpus Totara D. Don. Totara
Taxus baccata L. Yew

Pinaceae

Abies alba Mill. (*A. pectinata* D.C.) Silver fir
Abies balsamea (L.) Mill. Balsam fir
Abies concolor Lindl. & Gord. White fir
Abies grandis Lindl. Lowland white fir
Abies lasiocarpa (Hook.) Nutt. Alpine fir
Abies magnifica A. Murr. Red fir
Abies nobilis Lindl. Noble fir
Agathis alba (Lam.) Foxw. Amboyna pine
Agathis australis (Lamb.) Steud. Kauri pine
Araucaria angustifolia (Bert.) O. Ktze. (*A. brasiliana* Rich) Paraná pine
Araucaria araucana (Mol.) K. Koch. (*A. imbricata* Pav.) Monkey puzzle
Araucaria Cunninghamii Sweet. Moreton Bay pine
Chamaecyparis Lawsoniana (A. Murr.) Parl. Port Orford cedar
Chamaecyparis nootkatensis (Lamb.) Sudw. Alaska cedar
Chamaecyparis thyoides (L.) BSP. Southern white cedar
Juniperus communis L. Juniper
Juniperus virginiana L. Red cedar
Larix decidua Mill. European larch
Larix laricina (Du Roi) Koch. Tamarack. Larch
Larix occidentalis Nutt. Western larch
Libocedrus decurrens Torr. Incense cedar
Picea Abies (L) Karst. (*P. excelsa* (Lam.) Link.) Norway spruce
Picea Engelmannii Engelm. Engelmann spruce
Picea glauca (Moench.) Voss. (*P. canadensis* (Mill.) BSP.) White spruce
Picea mariana (Mill.) BSP. Black spruce
Picea rubens Sarg (*P. rubra* (Du Roi) Dietr.) Red spruce
Picea sitchensis (Bong.) Carr. Sitka spruce. Tideland spruce
Pinus Banksiana Lamb. Jack pine
Pinus caribaea Morelet (*P. cubensis* Gris.) (*P. heterophylla* (Ell.) Sudw.) Slash pine
Pinus contorta Dougl. Lodgepole pine
Pinus echinata Mill. Shortleaf pine
Pinus edulis Engelm. Piñon
Pinus halapensis Mill. Aleppo pine
Pinus Lambertiana Dougl. Sugar pine
Pinus monophylla Torr. Single-leaf piñon
Pinus monticola Dougl. Western white pine
Pinus nigra Arnold. (*P. Laricio* Poir.) Black pine. Corsican pine
Pinus palustris Mill. Longleaf pine. Southern yellow pine

Pinus Pinaster Sol. (*P. maritima* Poir.) Cluster pine. Maritime pine
Pinus Pinea L. Italian stone pine
Pinus ponderosa Doug. in Lawson. Western yellow pine
Pinus resinosa Ait. Red pine. Norway pine
Pinus Sabiniana Dougl. Digger pine
Pinus Strobus L. White pine
Pinus succinifera (Goppert) Conw. Baltic amber
Pinus sylvestris L. Scotch pine. Scots pine
Pinus Taeda L. Loblolly pine
Pinus Torreyana Parry ex Carr. Torrey pine
Pseudotsuga mucronata (Raf.) Sudw. (*P taxifolia* (Lam.) Britt.) Douglas fir
Sequoia gigantea (Lindl.) Decne Big tree
Sequoia sempervirens (Lam.) End. Redwood
Taxodium distichum (L) Rich. Bald cypress
Tetraclinis articulata (Vahl) Mast. (*Callitris quadrivalvis* Vent.) Sandarac
Thuja occidentalis L. Northern white cedar. Arbor vitae
Thuja plicata D. Don. Western red cedar
Tsuga canadensis (L.) Carr Eastern hemlock
Tsuga heterophylla (Raf.) Sarg Western hemlock
Tsuga Mertensiana (Bon.) Sarg. Mountain hemlock

Gnetaceae

Ephedra equisetina Bunge. Ma-huang
Ephedra sinica Stapf. Ma-huang

ANGIOSPERMAE

MONOCOTYLEDONAE

Pandanaceae

Pandanus tectorius Soland. Screw pine
Pandanus utilis Bory. Screw pine

Gramineae

Arundinaria sp. Bamboo
Avena brevis Roth. Short oat
Avena fatua L. Wild oat
Avena nuda L. Naked oat
Avena orientalis Schreb. Hungarian oat. Turkish oat
Avena sativa L. Common oat
Bambusa sp. Bamboo
Coix Lachryma-Jobi L. Job's-tears
Cymbopogon citratus (D.C.) Stapf. Lemon grass
Cymbopogon Martinii (Roxb.) Stapf. Ginger grass. Palmarosa
Cymbopogon Nardus (L.) Rendle. Citronella
Dendrocalamus sp. Bamboo
Echinochloa colona (L.) Link. Shama millet
Echinochloa crus-galli (L.) Beauv. Barnyard millet

Echinochloa frumentacea (Roxb.) Link. Japanese millet
Eleusine coracana (L.) Gaertn. Ragi. African millet
Epicampes macroura (HBK.) Benth. Broomroot. Zacaton
Euchlaena mexicana Schrad. Teosinte
Gigantochloa sp. Bamboo
Hierochloë odorata (L.) Beauv. Sweet grass
Hordeum distichon L. Two-rowed barley
Hordeum hexastichon L. Six-rowed barley
Hordeum vulgare L. Barley
Lygeum Spartum Loefl.
Oryza sativa L. Rice
Panicum miliaceum L. Proso millet
Pennisetum glaucum (L.) R. Br. Pearl millet
Phyllostachys sp. Bamboo
Saccharum officinarum L. Sugar cane
Secale cereale L. Rye
Secale montanum Guss. Wild rye
Setaria italica (L.) Beauv. Foxtail millet
Setaria viridis (L.) Beauv. Foxtail millet
Sorghum vulgare Pers. (*Andropogon Sorghum* (L.) Brot.) (*Holcus Sorghum* L.) Sorghum
  var. caffrorum (Retz) Hubb. & Rehder. Kafir
  var. caudatum (Hack.) A. F. Hill. Feterita
  var. cernuum (Ard.) Fiori & Paoli. White durra
  var. durra (Forsk.) Hubb. & Rehder. Brown durra
  var. nervosum (Hack.) Forbes & Hemsley. Kaoliang
  var. Roxburghii (Hack.) Haines. Shallu
  var. saccharatum (L.) Boerl. Sorgo
  var. subglabrescens (Steud.) A. F. Hill. Milo
  var. sudanensis (Piper) Hitchc. Sudan grass
  var. technicum (Koern.) Fiori & Paoli. Broomcorn
Stipa tenacissima L. Esparto
Triticum aestivum L. (*T. vulgare* Vill.) (*T. sativum* Lam.) Wheat
Triticum compactum Host. Club wheat
Triticum dicoccum Schrank. Emmer
Triticum durum Desf. Durum wheat
Triticum monococcum L. Einkorn
Triticum polonicum L. Polish wheat
Triticum Spelta L. Spelt
Triticum turgidum L. Poulard wheat
Vetiveria zizanioides (L.) Nash. Khuskhus. Vetiver
Zea Mays L. Maize. Indian corn
  var. erythrolepis (Bonaf.) Alef. (var. *amylacea* (Sturt.) Bailey.) Soft corn
  var. indentata (Sturt.) Bailey. Dent corn
  var. indurata (Sturt.) Bailey. Flint corn
  var. praecox Bonaf. (var. *everta* (Sturt.) Bailey.) Popcorn
  var. rugosa Bonaf. (var. *saccharata* (Sturt.) Bailey.) Sweet corn

var. tunicata St. Hil. Pod corn
Zizania aquatica L. Wild rice
var. angustifolia Hitchc. (*Z. palustris* L.) Wild rice

Cyperaceae

Cyperus Papyrus L. Papyrus
Cyperus tegetiformis Roxb. Chinese mat grass

Palmaceae

Areca Catechu L. Betel-nut palm
Arenga pinnata (Wurmb.) Merr. (*A. saccharifera* Labill.) Gomuti palm
Attalea funifera Mart. Bahia piassava
Borassus flabellifer L. Palmyra palm
Calamus sp. Rattan
Caryota urens L. Toddy palm
Ceroxylon andicola H. & B. Wax palm
Chamaerops humilis L. Fan palm
Cocos nucifera L. Coconut
Coelococcus amicarum (Wendl.) W. F. Wight. Ivory-nut palm
Copernicia cerifera (Arr.) Mart. Carnauba wax palm
Daemonorops Draco (Willd.) Bl. (*Calamus Draco* Willd.) Sumatra dragon's blood
Elaeis guineensis Jacq. Oil palm
Leopoldinia Piassaba Wallace. Para piassava
Metroxylon Sagu Rottb. (*M. Rumphii* Mart.) Sago palm
Orbignya Cohune (Mart.) Dahlgren. (*Attalea Cohune* Mart.) Cohune palm
Phoenix dactylifera L. Date palm
Phoenix sylvestris (L.) Roxb. Wild date
Phytelephas macrocarpa Ruiz & Pav. Ivory-nut palm. Tagua palm
Raphia pedunculata Beauv. (*R. Ruffia* Mart.) Raffia palm
Raphia vinifera Beauv. West African piassava. Wine palm
Sabal causiarum (Cook) Becc. (*Inodes causiarum* Cook.) Puerto Rico hat palm
Sabal Palmetto (Walt.) Lodd. (*Inodes Palmetto* (Walt.) Cook.) Palmetto

Cyclanthaceae

Carludovica palmata Ruiz & Pav. Panama hat palm.

Araceae

Acorus Calamus L. Sweet flag. Calamus root
Colocasia esculenta (L.) Schott. Dasheen
var. antiquorum (Schott) Hubb. & Rehder. Taro
Xanthosma sagittifolium Schott. Yautia

Bromeliaceae

Ananas comosus (L.) Merr. (*A. sativus* Schult. f.) Pineapple
Tillandsia usneoides L. Spanish moss

Juncaceae

Juncus effusus L. Rush

Liliaceae

Allium ascalonicum L. Shallot
Allium Cepa L. Onion
Allium Porrum L. Leek
Allium sativum L. Garlic
Allium Schoenoprasum L. Chives
Aloe ferox Mill. Cape aloes
Aloe Perryi Baker. Socotrine aloes
Aloe vulgaris Lam. (*A. vera* L.) Barbadoes aloes
Asparagus officinalis L. Asparagus
Chlorogalum pomeridianum (Ker-Gawl.) Kunth. California soaproot
Colchicum autumnale L. Meadow saffron. Colchicum root
Convallaria majalis L. Lily of the valley
Dracaena cinnabari Balf. f. Socotra dragon's blood
Hyacinthus orientalis L. Hyacinth
Phormium tenax Forst. New Zealand hemp
Sansevieria longifolia Sims. Florida bowstring hemp
Sansevieria Roxburghiana Schult. f. Indian bowstring hemp
Sansevieria thyrsiflora Thunb. (*S. guineensis* (Jacq.) Willd.) African bowstring hemp
Sansevieria zeylanica (Jacq.) Willd. Ceylon bowstring hemp
Smilax medica Schlecht. & Cham. Mexican sarsaparilla
Smilax officinalis HBK. Honduras sarsaparilla
Smilax ornatus Hook. f. Jamaican sarsaparilla
Urginea maritima (L.) Baker. Squills. Sea onion
Xanthorrhoea australis R. Br. Grass tree
Xanthorrhoea hastilis R. Br. Grass tree
Yucca sp. Palma istle

Amaryllidaceae

Agave atrovirens Karw. Pulque plant
Agave Cantala Roxb. Maguey
Agave fourcroydes Lem. Henequen. Yucatan sisal
Agave heteracantha Zucc. Jaumave istle
Agave Lecheguilla Torr. Tula istle
Agave sisalina Perrine. Sisal
Agave sp. Mexican maguey
Furcraea gigantea (D. Dietr.) Vent. (*F. foetida* (L.) Haw.) Mauritius hemp. Green aloe
Furcraea hexapetala (Jacq.) Urb. (*F. cubensis* (Jacq.) Vent.) Cuban hemp
Narcissus Jonquilla L. Jonquil
Narcissus Tazetta L. Narcissus
Polianthes tuberosa L. Tuberose

Dioscoreaceae

Dioscorea alata L. Yam

Iridaceae

Crocus sativus L. Saffron crocus
Iris florentina L. Orris

Musaceae

Musa nana Lour. (*M. Cavendishii* Lamb.) Dwarf banana
Musa paradisaica L. Plantain
subsp. sapientum (L.) O. Ktze. (*M. sapientum* L.) Banana
Musa textilis Née. Abacá. Manila hemp

Zingiberaceae

Aframomum Melegueta (Rosc.) K. Schum. Grains of paradise
Amomum sp. Grains of paradise
Curcuma angustifolia Roxb. East Indian arrowroot
Curcuma longa L. Turmeric
Curcuma zedoaria (Berg.) Rosc. Zedoary
Elettaria Cardamomum (L.) Maton. Cardamom
Languas Galanga (L.) Stuntz. (*Alpinia Galanga* (L.) Sw.) Greater galangal
Languas officinarum (Hance) Farwell. (*Alpinia officinarum* Hance) Lesser galangal
Zingiber officinale Rosc. Ginger

Cannaceae

Canna edulis Ker-Gawl. Queensland arrowroot

Marantaceae

Maranta arundinacea L. West Indian arrowroot

Orchidaceae

Vanilla fragrans (Salisb.) Ames. (*V. planifolia* Andr.) Vanilla
Vanilla Pompona Scheide. West Indian vanilla

DICOTYLEDONAE

Archychlamydeae

Piperaceae

Piper Betle L. Betel pepper
Piper Cubeba L. f. Cubeb
Piper longum L. Long pepper
Piper methysticum Forst. Kavakava
Piper nigrum L. Black pepper
Piper retrofractum Vahl. (*P. officinarum* C.D.C.) Long pepper

Salicaceae

Populus balsamifera L. (*P. deltoides* Marsh.) Cottonwood
Populus grandidentata Michx. Large-toothed aspen
Populus Tacamahacca Mill. (*P balsamifera* L.) Balsam poplar
Populus tremuloides Michx. Quaking aspen
Salix alba L. White willow
Salix nigra Marsh. Black willow

Myricaceae

Myrica carolinensis Mill. Bayberry
Myrica cerifera L. Wax myrtle

Juglandaceae

Carya alba (L.) K. Koch Mockernut
Carya glabra (Mill.) Sweet. Pignut
Carya ovata (Mill) K. Koch. Shagbark hickory
Carya Pecan (Marsh,) Eng. & Graeb (*C illinoensis* (Wang.) K. Koch.) Pecan
Juglans cinerea L. Butternut
Juglans nigra L. Black walnut
Juglans regia L. English walnut Persian walnut

Betulaceae

Alnus glutinosa (L.) Gaertn. European black alder
Alnus rubra Bong. Red alder
Betula lenta L. Black birch Sweet birch
Betula lutea Michx. f. Yellow birch
Betula papyrifera Marsh Paper birch. White birch
Betula pendula Roth (*B alba* L. in part.) European white birch
Betula pubescens Ehrh (*B alba* L. in part) European white birch
Carpinus Betulus L. European hornbeam
Carpinus caroliniana Walt. Blue beech
Corylus americana Walt. Hazelnut
Corylus Avellana L. Filbert European hazelnut
Corylus cornuta Marsh. (*C. rostrata* Ait.) Beaked hazelnut
Ostrya virginiana (Mill) K. Koch. Hop hornbeam

Fagaceae

Castanea crenata Sieb. & Zucc. Japanese chestnut
Castanea dentata (Marsh.) Borkh Chestnut
Castanea sativa Mill. (*C. vulgaris* Lam.) European chestnut
Fagus grandifolia Ehrh. Beech
Fagus sylvatica L. European beech
Lithocarpus densiflora (Hook. & Arn.) Rehder. California tanbark oak
Quercus Aegilops L. Turkish oak
Quercus alba L. White oak
Quercus bicolor L. Swamp white oak

Quercus borealis Michx. f. (*Q. rubra* DuRoi.) Red oak
Quercus Catesbaei Michx. Turkey oak
Quercus Cerris L. European turkey oak
Quercus coccinea Muench. Scarlet oak
Quercus conferta Ait.
Quercus Garryana Dougl. Oregon white oak
Quercus imbricaria Michx. Shingle oak
Quercus infectoria Oliv. Aleppo oak
Quercus lyrata Walt. Overcup oak
Quercus macrocarpa Michx. Bur oak
Quercus montana Willd. (*Q. Prinus* Endl.) Chestnut oak
Quercus palustris Muench. Pin oak
Quercus phellos L Willow oak
Quercus Prinus L. (*Q. Michauxii* Nutt.) Swamp chestnut oak
Quercus Robur L. English oak
Quercus sessiliflora Salisb.
Quercus stellata Wang. Post oak
Quercus Suber L. Cork oak
Quercus texana Buckley. Texas red oak
Quercus velutina Lam. Black oak
Quercus virginiana Mill. Live oak

Ulmaceae

Celtis occidentalis L. Hackberry
Ulmus americana L White elm
Ulmus fulva Michx. Slippery elm
Ulmus procera Salisb (*U. campestris* Mill. in part.) English elm
Ulmus racemosa Thom. Rock elm

Moraceae

Antiaris toxicaria (Pers.) Lesch. Upas tree
Artocarpus communis Forst. Breadfruit
Artocarpus integra (Thunb.) Merr. Jackfruit
Brosimum utile (HBK.) Pittier. (*B. Galactodendron* D. Don) Cow tree
Broussonetia papyrifera (L.) Vent Paper mulberry
Cannabis sativa L. Hemp
Castilla elastica Cerv. Panama rubber
Chlorophora tinctoria (L.) Gaud. Old fustic
Ficus Carica L. Fig
Ficus elastica Roxb. India rubber. Assam rubber
Ficus religiosa L.
Ficus utilis Sim.
Humulus Lupulus L. Hops
Maclura pomifera (Raf.) Schneid. Osage orange
Morus alba L. White mulberry
Morus nigra L. Black mulberry
Morus rubra L. Red mulberry

Piratinera guianensis Aubl. (*Brosimum Aubletii* P. & E.) Snakewood. Letterwood

Urticaceae

Bochmeria nivea (L.) Gaud. Ramie
var. tenacissima (Gaud.) Miquel. Rhea

Proteaceae

Grevillea robusta A. Cunn. Silky oak

Santalaceae

Santalum album L. Sandalwood

Polygonaceae

Coccoloba uvifera L. Sea grape
Fagopyrum esculentum Moench. Buckwheat
Rheum officinale Baill. Rhubarb
Rheum Rhaponticum L. Garden rhubarb
Rumex hymenosepalus Torr. Canaigre Tanner's dock

Chenopodiaceae

Beta maritima L. Wild beet
Beta vulgaris L. Garden beet Sugar beet Mangels
var. Cicla L. Chard
Chenopodium ambrosioides L., var. anthelminticum (L.) Gray. Wormseed
Chenopodium Quinoa Willd. Quinoa
Spinacia oleracea L. Spinach

Caryophyllaceae

Dianthus Caryophyllus L. Carnation
Saponaria officinalis L. Soapwort. Bouncing Bet

Ranunculaceae

Aconitum Napellus L. Aconite. Monkshood
Hydrastis canadensis L. Goldenseal

Berberidaceae

Podophyllum peltatum L. Mandrake. May apple

Magnoliaceae

Illicium verum Hook. f. Star anise
Liriodendron Tulipifera L. Tulip tree
Magnolia acuminata L. Cucumber tree
Michelia Champaca L. Champac

Annonaceae

Annona Cherimolia Mill. Cherimoya
Annona muricata L. Soursop

Annona reticulata L. Bullock's-heart
Annona squamosa L. Sweetsop
Asimina triloba (L.) Dunal. Papaw
Canangium odoratum (Lam.) Baill. apud King. Ylang-ylang
Oxandra lanceolata (Sw.) Baill. Lancewood

Myristicaceae

Myristica fragrans Houtt. Nutmeg

Lauraceae

Aniba panurensis Mez. Cayenne linaloe. Bois du rose
Cinnamomum Burmannii (Nees) Blume. Padang cassia
Cinnamomum Camphora (L.) T. Nees & Eberm. Camphor
Cinnamomum Cassia (Nees) Nees ex Blume. Cassia
Cinnamomum Loureirii Nees. Saigon cinnamon
Cinnamomum Massoia Schewe. (*Massoia aromatica* Becc.) Massoia bark
Cinnamomum Oliveri Bailey. Oliver's bark
Cinnamomum Tamala (Buch.-Ham.) T. Nees & Eberm. Indian cassia
Cinnamomum zeylanicum Breyn. Cinnamon
Laurus nobilis L. Laurel. Sweet bay
Nectandra Rodioei Schomb. Greenheart
Persea americana Mill. Avocado Alligator pear
Sassafras albidum Nees. (*S. variifolium* (Salisb.) Kuntze.) (*S. officinale* Nees & Eberm.) Sassafras

Papaveraceae

Argemone mexicana L. Mexican poppy
Papaver somniferum L. Opium poppy

Capparidaceae

Capparis spinosa L. Caper bush.

Cruciferae

Brassica alba (L.) Boiss. White mustard
Brassica campestris L. Field mustard
Brassica chinensis L. Chinese cabbage
Brassica juncea (L.) Cosson. Indian mustard
Brassica Napobrassica (L.) Mill. Rutabaga
Brassica Napus L. Rape
Brassica nigra (L.) Koch. Black mustard
Brassica oleracea L. Wild cabbage
var. acephala D.C. Borecole. Kale
var. botrytis L. Cauliflower. Broccoli
var. capitata L. Cabbage
var. gemmifera Zenk. Brussels sprouts
var. gongylodes L. (*B. caulorapa* Pasq.) Kohlrabi
Brassica pekinensis (Lour.) Rupr. Chinese cabbage
Brassica Rapa L. Turnip

Camelina sativa (L.) Crantz. False flax
Isatis tinctoria L. Woad
Raphanus sativus L. Radish
Rorippa Armoracia (L.) Hitchc. (*Armoracia rusticana* Gaertn.) Horse-radish
Rorippa Nasturtium-aquaticum (L.) Britt. & Rendle. Water cress

Resedaceae

Reseda Luteola L. Weld
Reseda odorata L. Mignonette

Moringaceae

Moringa oleifera Lam. (*M. pterygosperma* Gaertn.)

Saxifragaceae

Ribes americanum Mill Wild currant
Ribes Grossularia L. Gooseberry
Ribes hirtellum Michx. Wild gooseberry
Ribes nigrum L. Black currant
Ribes sativum Syme. (*R. vulgare* Lam.) Red currant

Hamamelidaceae

Hamamelis virginiana L. Witch hazel
Liquidambar orientalis Mill. Styrax
Liquidambar Styraciflua L. Red gum Sweet gum

Platanaceae

Platanus occidentalis L. Sycamore
Platanus orientalis L European plane tree

Rosaceae

Cydonia oblonga Mill. (*C. vulgaris* Pers.) Quince
Eriobotrya japonica (Thunb.) Lindl. Loquat
Fragaria chiloensis (L.) Duchesne. Strawberry
Fragaria vesca L. Strawberry
Fragaria virginiana Duchesne. Strawberry
Mespilus germanica L. Medlar
Prunus americana Marsh. Wild plum
Prunus Amygdalus Batsch. (*P. communis* (L.) Arcang.) Almond
var. amara D.C. Bitter almond
var. dulcis D.C. Sweet almond
Prunus Armeniaca L. Apricot
Prunus avium L. Sweet cherry
Prunus Cerasus L. Sour cherry
Prunus domestica L. European plum
Prunus hortulana Bailey. Hortulana plum
Prunus insititia L. Bullace plum
Prunus nigra Ait. Wild plum

Prunus Persica (L.) Sieb. & Zucc. Peach
var. nectarina (Ait.) Maxim. (var. *nucipersica* (L.) Schneid). Nectarine
Prunus salicina Lindl. Japanese plum
Prunus serotina Ehrh. Wild black cherry
Prunus serrulata Lindl. Japanese flowering cherry
Prunus spinosa L. Sloe. Blackthorn
Pyrus baccata L. (*Malus baccata* (L.) Borkh.) Siberian crab apple
Pyrus communis L. Pear
Pyrus Malus L. (*Malus pumila* Mill.) Apple
Pyrus serotina Rehd., var. culta Rehd. Chinese pear. Sand pear
Quillaja Saponaria Mol. Soapbark
Rosa centifolia L. Cabbage rose
Rosa damascena Mill. Damask rose
Rubus alleghaniensis Porter. Blackberry
Rubus argutus Link. Blackberry
Rubus flagellaris Willd. Dewberry
Rubus frondosus Bigel. Blackberry
Rubus Idaeus L. Red raspberry
var strigosus (Michx) Maxim Wild raspberry
Rubus loganobaccus Bailey. Loganberry
Rubus occidentalis L. Black raspberry
Rubus trivialis Michx. Dewberry
Rubus vitifolius C. & S California dewberry
Sorbus Aucuparia L. (*Pyrus Aucuparia* (L.) Ehrh.) Rowan

Leguminosae

Acacia arabica (Lam.) Willd. Babul
Acacia Catechu (L. f.) Willd. Black cutch. Catechu
Acacia dealbata (Page) Link. Wattle
Acacia decurrens (Wendl.) Willd. Black wattle
Acacia Farnesiana (L.) Willd. Cassie
Acacia melanoxylon R. Br. Australian blackwood
Acacia Senegal (L.) Willd. Gum arabic
Acacia pycnantha Benth. Golden wattle
Arachis hypogaea L. Peanut
Astragalus gummifer Labill. Gum tragacanth
Baphia nitida Afzel. ex Lodd. Barwood Camwood
Brya Ebenus (L.) D.C. Cocus wood. Granadillo. American ebony
Butea monosperma (Roxb.) Taub. (*B. frondosa* Roxb) Bengal kino
Caesalpinia brasiliensis (L) Sw. Brazilwood
Caesalpinia coriaria (Jacq.) Willd. Divi-divi
Caesalpinia Sappan L. Sappanwood
Cajanus Cajan (L.) Millsp. (*C. indicus* Spreng.) Cajan pea. Pigeon pea
Canavalia ensiformis (L.) D.C. Jack bean. Horse bean
Cassia acutifolia Del. Alexandrian senna
Cassia angustifolia Vahl. Indian senna
Cassia auriculata L. Avaram
Ceratonia Siliqua L. Carob

Cicer arietinum L. Chick pea
Copaifera Demeusii Harms. Congo copal
Copaifera Gorskiana Benth. Inhambane copal
Copaifera Guibortiana Benth. Sierra Leone copal
Copaifera Langsdorfii Desv. Copaiba balsam
Copaifera mopane J. Kirk. Congo copal
Copaifera officinalis L. Copaiba balsam
Copaifera Salikounda Heckel. Sierra Leone copal
Crotalaria juncea L. Sunn hemp
Dalbergia latifolia Roxb. Indian rosewood
Dalbergia nigra Fr. Allem. Brazilian rosewood
Dalbergia retusa Hemsl. Cocobolo
Dalbergia Sissoo Roxb. Sissoo
Daniella Ogea Rolfe. Accra copal. Benin copal
Daniella Oliveri (Rolfe) Hutch. & Dalz. Illurin balsam
Daniella thurifera Benn. Sierra Leone frankincense
Derris elliptica (Wall.) Benth. Tuba. Derris
Derris trifoliata (Lour.) Taub. (*D. uliginosa* (Roxb.) Benth.) Derris
Dimorphandra Mora B. & H. f. Mora
Dipteryx odorata (Aubl.) Willd. Tonka bean
Dipteryx oppositifolia (Aubl.) Willd. Tonka bean
Dolichos Lablab L. Hyacinth bean. Bonavist Lablab
Gleditsia triacanthos L. Honey locust
Glycine Soja (L.) Sieb. & Zucc. (*G. Max* (L.) Merr.) (*Soja Max* (L.) Piper.) Soybean
Glycyrrhiza glabra L. Licorice
Gymnocladus dioica (L.) K. Koch. Coffee tree
Haematoxylon Brasiletto Karst. Brazilette
Haematoxylon campechianum L. Logwood
Hymenaea Courbaril L. South American locust. West Indian locust
Indigofera suffruticosa Mill. Indigo
Indigofera tinctoria L. Indigo
Inga edulis Mart.
Lens esculenta Moench. Lentil
Lespedeza striata (Thunb.) H. & A. Bush clover
Lonchocarpus Nicou (Aubl.) D.C. Cubé
Medicago hispida Gaertn. Bur clover
Medicago lupulina L. Medic
Medicago sativa L. Alfalfa
Melilotus alba Desr. Sweet clover
Myroxylon Balsamum (L.) Harms. (*M. toluiferum* HBK.) Balsam of Tolu
Myroxylon Pereirae (Royle) Klotzsch. Balsam of Peru
Parkia biglobosa (Willd.) Benth. Nitta. African locust bean
Parkia filicoidea Welw. African locust bean
Peltogyne paniculata Benth. Purpleheart
Phaseolus aureus Roxb. Mung bean
Phaseolus lunatus L. Lima bean

Phaseolus multiflorus Willd. Scarlet runner bean
Phaseolus vulgaris L. Common bean
Pisum sativum L. Pea
Pongamia pinnata (L.) Pierre. (*P. glabra* (L.) Vent.) Pongam
Prosopis chilensis (Molina) Stuntz. (*P. juliflora* (Sw.) D.C.) Algaroba Mesquite. Keawe
Prosopis glandulosa Torr. Mesquite
Pterocarpus erinaceus Poir. West African kino
Pterocarpus indicus Willd. Padouk
Pterocarpus Marsupium Roxb Malabar kino
Pterocarpus santalinus L. f. Red sanderswood Red sandalwood
Pueraria Thunbergiana (Sieb. & Zucc.) Benth. (*P. hirsuta* Schneid.) Kudzu
Robinia pseudoacacia L. Black locust
Samanea Saman (Jacq.) Merr. (*Enterolobium Saman* (Jacq.) Prain.) Rain tree
Sesbania exaltata (Raf.) Rydb. (*S. macrocarpa* Muhl.) Colorado river hemp
Stizolobium Deeringianum Bort (*Mucuna Deeringiana* (Bort.) Merr.) Velvet bean
Tamarindus indica L. Tamarind
Trachylobium verrucosum (Gaertn.) Oliv. Zanzibar copal
Trifolium hybridum L. Alsike clover
Trifolium incarnatum L. Crimson clover
Trifolium pratense L. Red clover
Trifolium repens L. White clover
Trigonella Foenum-graecum L. Fenugreek
Vicia Faba L. Broad bean Windsor bean
Vicia sativa L. Vetch
Vicia villosa Roth. Hairy vetch
Vigna sinensis (L.) Savi. Cowpea
Xylia xylocarpa (Roxb.) Taub (*X. dolabriformis* Benth.) Acle Pyinkado

Geraniaceae

Pelargonium graveolens L'Her. Rose geranium
Pelargonium odoratissimum (L.) Ait. Rose geranium

Linaceae

Linum usitatissimum L. Flax

Erythroxylaceae

Erythroxylon Coca Lam. Coca

Zygophyllaceae

Guaiacum officinale L. Lignum vitae
Guaiacum sanctum L. Lignum vitae

Rutaceae

Amyris balsamifera L. American elemi
Amyris elemifera L. American elemi
Barosma betulina (Thunb.) Bartl. & Wendl. Buchu
Barosma crenulata (L.) Hook. Buchu
Barosma serratifolia (Curt.) Willd. Buchu
Chloroxylon Swietenia D.C. East Indian satinwood
Citrus aurantifolia (Christman) Swingle. Lime
Citrus Aurantium L. Sour orange. Seville orange. Bitter orange
Citrus Bergamia Risso. Bergamot
Citrus Limonia Osbeck. Lemon
Citrus maxima (Burm.) Merr. (*C. grandis* (L.) Osbeck.) Pomelo. Shaddock
var. uvacarpa Merr. & Lee. (*C. paradisi* Macfad.) Grapefruit
Citrus Medica L. Citron
Citrus mitis Blanco. Calamondin. Panama orange
Citrus nobilis Lour. King orange
var. deliciosa (Ten.) Swingle. Tangerine
var. unshiu (Mak.) Swingle. Satsuma orange
Citrus sinensis (L.) Osbeck. Sweet orange
Feronia Limonia (L.) Swingle. (*F. elephantum* Cor.) Elephant apple
Fortunella crassifolia Swingle Kumquat
Fortunella japonica (Thunb.) Swingle. Kumquat
Fortunella margarita (Lour.) Swingle. Kumquat
Poncirus trifoliata (L.) Raf. Trifoliate orange. Deciduous orange
Ruta graveolens L. Rue
Zanthoxylum flavum Vahl. West Indian satinwood

Simarubaceae

Picraena excelsa (Sw.) Lindl. (*Picrasma excelsa* (Sw.) Planch.) Jamaica quassia
Quassia amara L. Quassia

Burseraceae

Boswellia Carteri Birdw. Olibanum. Frankincense
Boswellia Frereana Birdw. African elemi
Boswellia serrata Roxb. Indian frankincense
Bursera aloexoxylon (Schlecht.) Engl. Mexican linaloe
Bursera Delpechianum Poiss. Mexican linaloe
Canarium luzonicum (Blume) A. Gray. Manila elemi
Canarium ovatum Engl Pili nut. Javanese almond
Canarium strictum Roxb. Black damar
Commiphora africana (Arn.) Engl. African bdellium
Commiphora erythraea (Ehrenb.) Engl. Bisabol myrrh Sweet myrrh
Commiphora Kataf (Forsk.) Engl Opopanax
Commiphora Mukul (Hook.) Engl. Indian bdellium
Commiphora Myrrha (Nees) Engl. Herabol myrrh

Commiphora Opobalsamum (L.) Engl. Mecca balsam
Protium heptaphyllum (Aubl.) March. Brazilian elemi

Meliaceae

Carapa guianensis Aubl. Crabwood
Carapa moluccensis Lam.
Cedrela odorata L. Spanish cedar. Cigar-box cedar
Cedrela Toona Roxb Moulmein cedar
Khaya senegalensis (Desr) A Juss. African mahogany
Swietenia Mahogani (L.) Jacq. Mahogany

Malpighiaceae

Banisteriopsis Caapi (Spruce) Morton. Caapi

Polygalaceae

Polygala Senega L Senega snakeroot

Euphorbiaceae

Aleurites Fordii Hemsl Tung-oil tree
Aleurites moluccana (L) Willd Candlenut. Lumbang
Aleurites montana (Lour) Wilson. (*A cordata* (A. Juss.) Steud.) Mu tree
Croton Tiglium L Croton
Euphorbia antisyphilitica Zucc
Euphorbia Intisy Drake del Castillo. Intisy
Hevea brasiliensis (HBK) Müll -Arg. Para rubber
Manihot esculenta Crantz (*M. utilissima* Pohl.) Cassava
Manihot Glaziovii Mull -Arg Ceara rubber
Pedilanthus Pavonis Boiss Candelilla wax
Ricinus communis L Castor bean
Sapium sebiferum (L) Roxb. Chinese vegetable tallow

Buxaceae

Buxus sempervirens L. Turkish boxwood

Anacardiaceae

Anacardium occidentale L. Cashew
Cotinus coggygria Scop. (*Rhus Cotinus* L) Smoke tree
Mangifera indica L. Mango
Melanorrhoea usitata Wall. Burmese lacquer tree
Pistacia cabulica Stocks. Bombay mastic
Pistacia lentiscus L. Chios mastic
Pistacia vera L. Pistachio. Green almond
Rhus chinensis Mill. (*R. semialata* Murr) Chinese sumac
Rhus copallina L. Dwarf sumac
Rhus coriaria L. Sicilian sumac
Rhus glabra L. Smooth sumac
Rhus succedanea L f. Japanese wax tree
Rhus typhina L. Staghorn sumac

Rhus vernicıflua Stokes. Lacquer tree
Schinopsis Lorentzii (Griseb.) Engl. (*Quebrachıa Lorentzıı* Griseb.) Quebracho

Aquıfolıaceae

Ilex Aquifolium L. European holly
Ilex Cassine L. Dahoon. Cassine
Ilex opaca Ait. Holly
Ilex paraguarıensis St. Hıl. Maté Paraguay tea
Ilex vomitorıa Aıt. Yaupon. Cassıne

Celastraceae

Catha edulis Forsk. Khat

Aceraceae

Acer macrophyllum Pursh. Oregon maple
Acer nigrum Michx. Black maple
Acer pseudoplatanus L. Sycamore maple
Acer rubrum L. Red maple
Acer saccharinum L. Silver maple
Acer saccharum Marsh. Sugar maple

Sapindaceae

Lıtchi chınensis Sonn. Litchi
Paullınia Cupana HBK. Guarana
Sapindus Saponaria L. Soapberry
Schleichera oleosa (Lour.) Merr. (*S. trijuga* Willd.) Lac tree

Hippocastanaceae

Aesculus octandra Marsh. Yellow buckeye

Rhamnaceae

Rhamnus cathartica L. Buckthorn
Rhamnus Frangula L. Alder buckthorn
Rhamnus globosa Bge. (*R. chlorophora* Decne.) Lokao
Rhamnus infectoria L. Persian berries
Rhamnus Purshıana D.C. Cascara sagrada
Rhamnus utılıs Decne. Lokao. Chınese buckthorn
Zizyphus Jujuba Mill Jujube. Chınese date
Zizyphus xylopyrus Willd. Jujube

Vıtaceae

Vitis aestıvalıs Michx. Summer grape
Vitis Labrusca L. Fox grape
Vitis rotundifolıa Mıchx. Muscadine grape
Vitis vinifera L. Wine grape
Vitıs vulpina L. Frost grape

Tiliaceae

Corchorus capsularis L. Jute
Corchorus olitorius L. Jute
Tilia cordata Mill. European linden. Lime
Tilia glabra Vent. (*T. americana* L.) Basswood Linden

Malvaceae

Abutilon Avicennae Gaertn. China jute Indian mallow
Althaea officinalis L. Marshmallow
Gossypium barbadense L. Sea-island cotton Egyptian cotton
Gossypium herbaceum L Asiatic cotton
Gossypium hirsutum L. Upland cotton
Gossypium peruvianum Cav. Peruvian cotton
Hibiscus cannabinus L. Gambo hemp Deccan hemp Ambari hemp
Hibiscus elatus Sw. Blue mahoe Cuba bast
Hibiscus esculentus L. (*Abelmoschus esculentus* (L.) Moench.) Okra
Hibiscus Sabdariffa L. Roselle. Rama
Hibiscus tiliaceus L. Mahoe. Majagua
Sida rhombifolia L. Cuba jute
Urena lobata L. Aramina

Bombacaceae

Adansonia digitata L. Baobab
Bombax Ceiba L. (*B. malabaricum* D.C.) Red silk cotton
Ceiba pentandra (L.) Gaertn. Kapok
Durio zibethinus L. Durian
Ochroma pyramidale (Cav.) Urb. (*O. Lagopus* Sw.) Balsa

Sterculiaceae

Cola nitida (Vent.) A. Chev. (*C. acuminata* (Beauv.) Schott & Endl.) Cola
Sterculia urens Roxb.
Theobroma Cacao L. Cocoa Cacao

Ternstroemiaceae

Camellia Sasanqua Thunb.
Camellia sinensis (L.) O. Ktze. (*Thea sinensis* L.) Tea

Guttiferae

Calophyllum inophyllum L. Indian laurel. Laurelwood
Garcinia Hanburyi Hook. f. Gamboge tree
Garcinia Mangostana L. Mangosteen
Mammea americana L. Mammee apple

Dipterocarpaceae

Balanocarpus Heimii King. Damar Penak
Dipterocarpus turbinatus Gaertn. f. Gurjun balsam

Dryobalanops aromatica Gaertn. f. Borneo camphor
Hopea micrantha Hook. f. Damar Mata Kuching
Shorea aptera Burck. Borneo tallow
Shorea crassifolia Ridl. Damar Temak
Shorea robusta Gaertn. f. Sal
Shorea Wiesneri Schiffn. Batavian damar
Vateria indica L. White damar

Bixaceae

Bixa Orellana L. Annatto

Cochlospermaceae

Cochlospermum Gossypium D.C. White silk cotton

Violaceae

Viola odorata L. Violet

Flacourtiaceae

Casearia praecox Griseb Venezuelan boxwood Zapatero
Hydnocarpus Kurzii (King) Wrbg. (*Taraktogenos Kurzii* King) Chaulmoogra

Passifloraceae

Passiflora edulis Sims. Purple granadilla
Passiflora ligularis A Juss. Sweet granadilla
Passiflora quadrangularis L. Giant granadilla

Caricaceae

Carica Papaya L. Papaya. Papaw

Cactaceae

Lophophora Williamsii (Lem.) Coult. Peyote Mescal buttons

Thymelaeaceae

Daphne cannabina Wall.
Edgeworthia Gardneri (Wall.) Meisn. (*E papyrifera* Sieb. & Zucc.)
Lagetta lintearia Lam. Lace bark
Wickstroemia canescens (Wall.) Meisn.

Lythraceae

Lawsonia inermis L. Henna

Punicaceae

Punica Granatum L. Pomegranate

Lecythidaceae

Bertholletia excelsa Humb. & Bonp. Brazil nut
Cariniana pyriformis Miers. Colombian mahogany

Couratari Tauari Berg. Tauary
Lecythis Zabucajo Aubl. Paradise nut. Sapucaia nut

Rhizophoraceae

Rhizophora Mangle L. Mangrove

Combretaceae

Anogeissus latifolia Wall. Gum ghatti
Terminalia Bellerica (Gaertn.) Roxb. Myrobalan
Terminalia chebula Retz. Myrobalan

Myrtaceae

Eucalyptus diversicolor F.v.M. Karri
Eucalyptus dives Schau
Eucalyptus globulus Labill. Blue gum
Eucalyptus marginata Sm. Jarrah
Eucalyptus occidentalis Endl Mallet bark
Eucalyptus rostrata Schlecht. Red gum
Eugenia caryophyllata Thunb. (*E. aromatica* (L.) Baill.) Clove
Eugenia cauliflora (Berg) D.C. (*Myrciaria cauliflora* Berg.) Jaboticaba
Eugenia Jambos L. Rose apple
Eugenia uniflora L. Surinam cherry Pitanga
Feijoa Sellowiana Berg. Feijoa
Melaleuca Leucadendron L. Cajeput
Pimenta acris Kostel. (*Amomis caryophyllata* (Jacq) Krug & Urb.) Bay
Pimenta officinalis Lindl. Allspice
Psidium Guajava L. Guava

Araliaceae

Panax Ginseng C. A. Mey. Ginseng
Panax quinquefolium L. American ginseng
Tetrapanax papyriferum (Hook f) C. Koch (*Fatsia papyrifera* Hook. f.) Rice paper plant

Umbelliferae

Anethum graveolens L. Dill
Angelica Archangelica L. (*Archangelica officinalis* Hoffm) Angelica
Anthriscus Cerefolium (L) Hoffm. Chervil
Apium graveolens L. Celery
var. rapaceum D.C. Celeriac
Carum Carvi L. Caraway
Coriandrum sativum L. Coriander
Cuminum Cyminum L. Cumin
Daucus Carota L. Carrot
Dorema Ammoniacum D Don Ammoniacum
Ferula assafoetida L Asafetida
Ferula galbaniflua Boiss. & Buhse. Galbanum

Foeniculum vulgare Miller. Fennel
var. dulce Alef. Florence fennel. Finochio
Levisticum officinale Koch. Lovage
Opopanax Chironium (L) Koch. Opopanax
Pastinaca sativa L. Parsnip
Petroselinum hortense Hoffm. (*Apium Petroselinum* L.) Parsley
Pimpinella Anisum L Anise

Cornaceae

Cornus florida L. Dogwood
Nyssa aquatica L Tupelo
Nyssa sylvatica Marsh. Sour gum. Black gum. Tupelo

Metachlymydeae

Ericaceae

Erica arborea L. Briar root
Gaultheria procumbens L. Checkerberry Wintergreen
Gaylussacia baccata (Wang.) C Koch. Huckleberry
Vaccinium atrococcum (Gray) Heller High-bush blueberry
Vaccinium canadense Kalm. Low-bush blueberry
Vaccinium corymbosum L. High-bush blueberry
Vaccinium macrocarpon Ait. Cranberry
Vaccinium Oxycoccus L. Small cranberry
Vaccinium pennsylvanicum Lam. Low-bush blueberry
Vaccinium vacillans Kalm. Low-bush blueberry
Vaccinium Vitis-Idaea L. Foxberry
var minus Lodd. Mountain cranberry

Sapotaceae

Achras Zapota L. Chicle. Sapodilla. Naseberry
Butyrospermum Parkii (G. Don) Kotschy. Shea butter
Madhuca butyracea (Roxb) Macb. (*Bassia butyracea* Roxb) Bassia fat
Madhuca indica J. F. Gmel. (*Bassia latifolia* Roxb.) Illipe butter
Madhuca longifolia (L.) Macb. (*Bassia longifolia* L) Mowra fat
Manilkara bidentata (A D.C.) A Chev. (*Mimusops Balata* Pierre.) Balata
Mimusops sp Cow tree
Palaquium Gutta (Hook.) Burck. Gutta-percha

Ebenaceae

Diospyros Ebenum Koenig. Macassar ebony
Diospyros Kaki L f. Japanese persimmon. Kaki
Diospyros virginiana L. Persimmon

Styracaceae

Styrax benzoides Craib Siam benzoin
Styrax Benzoin Dryand. Sumatra benzoin

Styrax tonkinense Craib. Siam benzoin

Oleaceae

Fraxinus americana L. White ash
Fraxinus excelsior L. European ash
Fraxinus nigra Marsh. Black ash
Fraxinus oregona Nutt. Oregon ash
Fraxinus Ornus L. Manna ash
Fraxinus pennsylvanica Marsh. Red ash
var. lanceolata (Borkh.) Sarg. Green ash
Fraxinus quadrangulata Michx. Blue ash
Jasminum grandiflorum L. Jasmine
Olea europaea L. Olive
Syringa vulgaris L Lilac

Loganiaceae

Strychnos Nux-vomica L. Nux vomica

Gentianaceae

Gentiana lutea L. Gentian

Apocynaceae

Apocynum cannabinum L. Indian hemp
Couma guatemalensis Standley. Cow tree
Dyera costulata (Miq) Hook. f. Jelutong
Funtumia elastica (Preuss.) Stapf. Lagos silk rubber
Landolphia Heudelotii A.D.C. Guinea landolphia rubber
Landolphia Kirkii Dyer Mozambique landolphia rubber
Landolphia owariensis Beauv. West African landolphia rubber
Strophanthus hispidus P.D.C. Strophanthus
Strophanthus Kombe Oliv. Strophanthus

Asclepiadaceae

Asclepias curassavica L. False ipecac. Blood flower
Asclepias subulata Decaisne. Desert milkweed
Asclepias syriaca L. Common milkweed
Calotropis gigantea (Willd.) Dryand. in Ait. Madar
Calotropis procera (Ait.) Dryand. in Ait. Akund

Convolvulaceae

Convolvulus Scammonia L. Scammony
Ipomoea Batatas (L.) Poir. Sweet potato
Ipomoea purga Hayne. (*Exogonium purga* (Hayne) Lindl.) Jalap

Boraginaceae

Alkanna tinctoria (L.) Tausch. Alkanna
Borago officinalis L. Borage
Heliotropium peruvianum L. Heliotrope

Verbenaceae

Tectona grandis L. f. Teak

Labiatae

Hedeoma pulegioides (L.) Pers. Pennyroyal
Hyssopus officinalis L. Hyssop
Lavandula latifolia Vill. (*L. Spica* D.C.) Spike lavender
Lavandula officinalis Chaix. (*L. Spica* L.) (*L. vera* D.C.) Lavender
Marjorana hortensis Moench. (*Origanum Marjorana* L.) Sweet marjoram
Marrubium vulgare L. Hoarhound
Melissa officinalis L. Balm
Mentha arvensis L., var. piperascens Malinv. Japanese peppermint
Mentha piperita L. Peppermint
Mentha Pulegium L. European pennyroyal
Mentha spicata L. Spearmint
Nepeta Cataria L. Catnip
Ocimum Basilicum L. Basil
Origanum vulgare L Pot marjoram
Perilla frutescens(L) Britton (*P. ocimoides* L.) Perilla
Pogostemon Cablin (Blanco) Benth Patchouli
Rosmarinus officinalis L Rosemary
Salvia officinalis L. Sage
Salvia Sclarea L. Clary
Satureja hortensis L. Summer savory
Satureja montanum L. Winter savory
Thymus vulgaris L Thyme

Solanaceae

Atropa Belladonna L. Belladonna
Capsicum frutescens L. (*C. annuum* L.) Red pepper
var. grossum (L.) Bailey. Sweet pepper. Bell pepper
var. longum (D C.) Bailey. Cayenne pepper. Chili
Datura arborea L. Maikoa
Datura Stramonium L. Jimson weed. Thorn apple. Stramonium
Duboisia Hopwoodii F v.M. Pituri
Hyoscyamus muticus L. Henbane
Hyoscyamus niger L. Black henbane
Lycopersicon esculentum Mill. Tomato
Nicotiana rustica L. Tobacco
Nicotiana Tabacum L. Tobacco
Solanum Melongena L. Eggplant. Aubergine
Solanum tuberosum L. Potato

Scrophulariaceae

Digitalis purpurea L Foxglove. Digitalis

Bignoniaceae

Catalpa speciosa Warder. Catalpa
Tabebuia Donnell-Smithii Rose. Prima vera

Pedaliaceae

Sesamum indicum L (*S. orientale* L.) Sesame

Plantaginaceae

Plantago Psyllium L. Psyllium Flea wort

Rubiaceae

Calycophyllum candidissimum (Vahl) D.C. Degame
Cephaelis Ipecacuanha (Brot) A Rich. (*Psychotria Ipecacuanha* Stokes.) Ipecac
Cinchona Calisaya Wedd Quinine
Cinchona Ledgeriana Moens. Quinine
Cinchona officinalis L. Quinine
Cinchona succirubra Pav. Quinine
Coffea arabica L. Coffee
Coffea liberica Bull Coffee
Coffea robusta Linden. Coffee
Rubia tinctorum L. Madder
Uncaria Gambir (Hunt.) Roxb. White cutch Gambier

Valerianaceae

Valeriana officinalis L. Garden heliotrope. Valerian

Cucurbitaceae

Citrullus Colocynthis (L.) Schrad Colocynth. Bitter apple
Citrullus vulgaris Schrad. Watermelon
var. citroides Bailey. Citron melon
Cucumis Anguria L. Gherkin
Cucumis Melo L. Melon
Cucumis sativus L. Cucumber
Cucurbita maxima Duchesne. Winter squash
Cucurbita moschata Duchesne. Squash
Cucurbita Pepo L Pumpkin. Summer squash
Luffa cylindrica (L) M. Roem Vegetable sponge
Sechium edule (Jacq.) Sw. Chayote

Campanulaceae

Lobelia inflata L. Indian tobacco

Compositae

Anthemis nobilis L Russian chamomile
Artemisia Absinthium L. Wormwood
Artemisia Cina Berg. Levant wormseed. Santonica

Artemisia Dracunculus L. Tarragon
Carthamnus tinctorius L. Safflower
Chrysanthemum cinerariaefolium (Trev.) Bocc. Dalmatian insect flowers
Chrysanthemum coccineum Willd Persian insect flowers
Chrysanthemum Marschallii Aschers. Caucasian insect flowers
Cichorium Endivia L. Endive
Cichorium Intybus L. Chicory
Cynara Scolymus L. Artichoke
Dahlia pinnata Cav. Dahlia
Guizotia abyssinica (L f.) Cass. Niger-seed
Helianthus annuus L. Sunflower
Helianthus tuberosus L. Jerusalem artichoke
Lactuca sativa L. Lettuce
Lactuca Scariola L. Wild lettuce
Matricaria Chamomilla L German chamomile
Parthenium argentatum A. Gray. Guayule
Solidago Leavenworthii T & G Goldenrod
Tanacetum vulgare L Tansy
Taraxacum officinale Weber Dandelion
Tragopogon porrifolius L. Oyster plant. Salsify

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