THE MICROSCOPY

OF

VEGETABLE FOODS

WITH SPECIAL REFERENCE TO

THE DETECTION OF ADULTERATION AND THE DIAGNOSIS OF MIXTURES

green

BY

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PREFACE.

THE development of vegetable histology, both as a pure and an applied science, has been largely in the hands of continental investigators. A generation ago Sachs, De Bary, and other histologists labored on the purely scientific problems; since then Vogl, Moeller, Tschirch, T. F. Hanausek, Oesterle, Planchon, Collin, Höhnel, Macé, and other technical microscopists, without neglecting research problems, have developed microscopical methods for the diagnosis of foods, drugs, and fibers which rank with chemical methods in practical importance.

The extensive literature in the German and French languages on the microscopy of foods includes several comprehensive works devoted exclusively to the subject, a still greater number covering either the wider range of foods and drugs or limited to special fields, such as cereal products and cattle foods, as well as numerous papers in botanical, pharmaceutical, and technical journals.

In English the dearth of literature on a subject of such scientific and technical importance is noteworthy. No single work devoted exclusively to food microscopy has hitherto appeared, although Hassall, Leach, and some other analysts, have described microscopical as well as chemical methods, and other authors, notably Greenish, Kraemer, and Jelliffe, have treated on the microscopy of both foods and drugs.

The present work is designed for the use of the food analyst, the agricultural chemist, the pharmacist, and others engaged in the examination of foods, as well as the physician who may be called upon to identify vegetable substances in stomach contents and fæces. It aims to be comprehensive, covering the important vegetable foods for man and cattle, and at the same time sufficiently concise for ready reference.

The idea that a scientific grounding is essential for practical work is paramount throughout. Only by a systematic study of each product from the morphological and physiological standpoint can one hope to develop keen observation and secure lasting impressions.

The work is closely affiliated with the second edition of Moeller's "Mikroskopie der Nahrungs- und Genussmittel," which appeared a few months since with the collaboration of the writer. The descriptions of the individual leaves, flowers, barks, roots, and edible fungi, with few exceptions, are translations of Professor Moeller's text, and no less than 350 cuts are also his. It is with the deepest gratitude that the writer acknowledges this generous coöperation of his honored teacher and friend. Had it not been for Professor Moeller's unselfish aid, the writer would never have undertaken investigations in this field, much less a comprehensive treatise.

Valuable cuts have been borrowed from the following well-known authors: Berg, Collin and Perrot, Frank, Gilg, Hager, Halström, T. F. Hanausek, Hartig, Hassall, Kny, Leach, Luerssen, Malfatti, A. Meyer, Mez, R. Müller, Nees, Nobbe, Planchon and Collin, Sachs, Schimper, Schumann, Tschirch, Tschirch and Oesterle, Tulasne, Villiers and Collin, Vogl, Warburg, and Wittmack and Buchwald. Numerous cuts, made from the writer's drawings for publications of the Connecticut Agricultural Experiment Station, are reproduced with the kind permission of that institution. Acknowledgment for the use of cuts is also due the following publishers: Julius Springer, Berlin (publisher of Moeller's Mikroskopie); The Clarendon Press, Oxford; Octave Doin, Paris; Wm. Engelmann, Leipsig; Ferdinand Enke, Stuttgart; Gustav Fischer, Jena; Carl Gerold's Sohn, Vienna; H. Haessell, Leipsig; Alfred Hölder, Vienna; A. Joanin & Cie., Paris; Longmans, Green, & Co., London; Paul Parey, Berlin; Chr. Herm. Tauchnitz, Leipsig; Urban & Schwarzenberg, Berlin and Vienna; J. J. Weber, Leipsig; Weidmannsche Buchhandlung, Berlin. Permission to reproduce Fig. 16 was kindly granted by Mr. E. Goodwin Clayton, F.I.C., F.C.S., consulting chemist, 32 Holborn Viaduct, London, England. The larger part of Professor Moeller's and the writer's drawings were reproduced on wood by F. X. Matolony of Vienna.

In the preparation of the text the works of the leading authors have been consulted, and credit has frequently been given for important discoveries, although so far as possible the writer has based his descriptions on his own observations. The descriptions of cucurbitaceous fruits and three excellent cuts illustrating the structure of the pumpkin were contributed by Miss Kate G. Barber.

The bibliographies throughout the work and the glossary are largely the work of my wife, who has devoted much time and thought to other details.

Professor Moeller's analytical key to commercial starches will be found a reliable guide in diagnosis. It is hoped the writer's keys to cereals, cruciferous seeds, umbelliferous fruits, legumes, and spices will also prove of value, although they are not universally applicable since many materials lack certain histological elements present in the original product.

The indulgence of the reader is asked for omissions of which the writer is painfully aware, and for errors which doubtless will be detected.

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PART I.

PRELIMINARY: EQUIPMENT, METHODS AND GENERAL PRINCIPLES.

THE MICROSCOPY OF VEGETABLE FOODS.

INTRODUCTION.

THE MICROSCOPY OF VEGETABLE FOODS is an applied analytical science having for its purpose the identification of food products of vegetable origin by the microscopic structure and microchemical reactions of their tissues and cell-contents.

It is a branch of Analytical Vegetable Histology, other important branches being the Microscopy of Drugs, or Microscopic Pharmacognosy, and the Microscopy of Fibers.

Preliminary Study. As the microscopy of foods, like the allied branches of analytical histology, is a department of applied botany, it cannot be properly taken up until after a course of instruction in the parent science, especially that part relating to the histology or microscopic anatomy of phanerogamic plants. To omit this is as irrational as to undertake the study of analytical chemistry without previous knowledge of general chemistry.

This training in botany need not, however, be more than is given in a good high-school course with practical histological work, although a supplementary course in the histology of phanerogams is highly desirable.

The student should begin his work in food microscopy with a systematic study of the most important seeds, fruits, leaves, flowers, roots, and barks used as foods or food adulterants. This work should include: (1) the macroscopic anatomy; (2) the histology as studied in transverse (less often longitudinal or tangential) sections; (3) the histology as studied in surface preparations of the successive layers obtained by scraping or stripping; and (4) the microscopic characters of the powdered, pulped, or macerated material. Macroscopic preparations show the general nature and relative size of the parts; cross-sections, the number of layers, order of arrangement, and certain details of structure; surface mounts, the details of cell structure most useful in practical work; and mounts of the powdered material, much that is learned from surface mounts and in addition the characters of the isolated cell-elements and cell-contents. The student who has not the time, apparatus, or technique for cutting careful sections can use permanent mounts of a collection, or can even depend on illustrations of such sections, but he should prepare his own mounts for the study of each material in surface view or powder form.

After this general work, which is analogous to the study of the reactions of the several bases and acids in his course in analytical chemistry, the student is prepared to undertake the diagnosis of mixtures. In this work he will find that of some materials, such, for example, as ground coffee, he can pick out fragments large enough for cutting sections, or preparing surface mounts by scraping, but as a rule he must depend entirely on the microscopic appearance of the powder. His knowledge gained by his study of sections and surface mounts of standard material will, however, be invaluable to him in interpreting the results of his examinations of powders.

The object of this book is to aid both the student and the practical worker, assuming that both are familiar with the general principles of elementary botany, vegetable histology, and microtechnique, or at least are in a position to use intelligently reference works on these subjects.

Relation to Chemical Analysis. Although the work of microscopic examination is distinctly botanical, its chief value is in conjunction with chemical analysis, and for this reason is more often undertaken by the analyst with a moderate knowledge of vegetable histology than by the professional botanist. Only in large institutions can the work be divided among specialists.

Both analytical chemistry and analytical histology, although widely unlike in their processes, are used in solving problems relating to the nature or purity of powdered foods, drugs, and other products of vegetable origin. Sometimes one line of investigation alone is useful, sometimes the other, but often each throws some light on the problem, thus furnishing an indisputable chain of evidence.

Analytical chemistry determines the amount of fiber, starch, protein, oil, etc.; analytical histology, the shape, size, reactions, and other characteristics of the cells and cell-contents. Analytical chemistry usually stops with the mere determination of the amount of chemical constituents; analytical histology goes further, and names the seeds, roots, barks, or other vegetable products from which the material was prepared. Analytical chemistry answers a question in scientific terms; analytical histology in terms which all can understand.

In many cases a satisfactory idea of a material is gained only by following out both lines of investigation. By chemical analysis we learn the percentage of protein, fiber, starch, etc., but not the ingredients from which they were derived; by microscopic analysis we learn the ingredients, but gain little idea of their proportion; but given the results of both analyses, we may often calculate approximately the percentage of the different materials present.

If, for example, we find in ground cloves 5 per cent instead of 15 per cent of essential oil, and 40 per cent instead of 8 per cent of fiber, we know it is not pure cloves; if we find under the microscope a large amount of stone cells and other tissues of the cocoanut shell, we learn the adulterant. Knowing all this, and knowing the average percentage of volatile oil in cloves and of fiber in both cloves and cocoanut shells, we have the data for calculating roughly the percentage of each in the mixture.

Mineral salts and other inorganic constituents of a mixture are identified by chemical or microchemical tests, and the amounts present determined by chemical methods.

BIBLIOGRAPHY.[1]

Elementary Botany.

BERGEN: The Foundations of Botany. Boston, 1903.
BESSEY: Botany for High Schools and Colleges. New York, 1880.
LEAVITT: Outlines of Botany. New York.

Structural Botany.

GRAY: Structural Botany. New York, 1880.

Vegetable Histology.

See p. 25.

Microscopy of Drugs.

GREENISH: Foods and Drugs. London, 1903.
JELLIFFE: Introduction to Pharmacognosy. Philadelphia, 1904.
KRAEMER: A Course in Botany and Pharmacognosy. Philadelphia, 1902.

Microscopy of Fibers.

MATHEWS: The Textile Fibers. New York, 1904.

Chemistry of Foods.

BATTERSHALL: Food Adulteration and its Detection. New York, 1887.
BELL: The Chemistry of Foods. London, 1881.
BLYTH: Foods, their Composition and Analysis. London, 1903.
HASSALL: Food, its Adulteration and the Methods for their Detection. London, 1876.
LEACH: Food Inspection and Analysis. New York, 1904.
LEFFMANN and BEAM: Select Methods of Food Analysis. Philadelphia, 1905.
U. S. Dept. Agr., Bur. Chemistry, Bulletins 13, 46, and 65.

[1] Works in English.

APPARATUS.

It is beyond the province of this work to describe the construction of the microscope and microscopic apparatus, or give instructions for their care and use. Those who desire information of this nature are referred to the works named on p. 19 and the pamphlets issued by the leading makers of instruments.

The list of apparatus which follows is designed merely as a guide for the purchaser.

Essential Apparatus. The apparatus described under this head is essential for the most elementary work in food microscopy; on the other hand, it is sufficient for verifying nearly all the descriptions in this volume, and for undertaking most of the problems encountered in practical work.

Compound Microscope. The stand should be of the Continental type, and should be provided with two objectives, a double nose-piece, two eye-pieces, an eye-piece micrometer, and a substage diaphragm.

A satisfactory range in magnification is secured by $\frac{3}{4}$ and $\frac{1}{6}$ objectives and 1- and 2-inch eye-pieces, of English and American makers, or Nos. 2 and 6 objectives and II and IV eye-pieces of Continental makers.

A simple form of eye-piece micrometer is suited for our purpose. It may be calibrated by means of a stage micrometer.

The double nose-piece, enabling the worker instantly to change from one objective to the other, is an inexpensive convenience that adds so much to the utility of the instrument that it may be regarded as a necessity.

For ordinary work the only substage attachments needed are the mirror and a simple diaphragm, but the substage should be of such a construction as to permit the introduction of a substage condenser and an iris diaphragm.

Simple Microscope. A pocket lens will answer the purpose, but an instrument with a stage and adjustable arm for the lenses is much more convenient.

Turn-table with centering pins for ringing permanent mounts.

Section Razor. This should be plano-concave and have a keen, thin edge for cutting soft tissues. Another razor with a stronger edge is useful for cutting hard materials.

Hone.

Strop.

Dissecting-needle Handles with interchangeable needles.

Scalpel.

Forceps with fine points.

Slides of the usual size (3×1 inch) may be obtained either of thick or thin glass, as preferred.

Cover-glasses. No. 2 round cover-glasses $\frac{3}{4}$ inch in diameter are recommended for both temporary and permanent mounts.

Reagent Bottles with stopper pipettes ground into the neck.

Watch-glasses.

Supplementary Apparatus. The following accessories, although not essential for ordinary work, should be in every well-appointed microscopical laboratory.

A Substage Condenser with an iris diaphragm attached is valuable in securing sufficient illumination on dark days.

Polarizing Apparatus.[1] This apparatus is useful chiefly in the examination of starch grains, crystals, and thickened cell-walls. It consists of two Nicol prisms, one (the polarizer) mounted in the substage, the other (the analyzer) in the tube or above the eye-piece. Selenite plates for use with the polarizing apparatus may be mounted either in a revolving disk in the substage, or in a metal slip for use on the stage under the object-slide.

A Mechanical Stage is of service in examining systematically every portion of a mount. A detachable form is recommended, as there are many times when this attachment is a hindrance rather than a convenience.

Microtome. This instrument is of value in preparing uniformly thin sections, particularly of soft tissues. In preparing a series of sections it is invaluable. It is, however, an instrument for special investigation, and not for practical food examination.

Paraffine Bath. For use in paraffine embedding.

Camera Lucida. Useful in making drawings.

Photomicrographic Apparatus. This is especially useful in preparing exhibits for court cases.

[1] A convenient micropolariscope, arranged for instantly changing from plain to polarized light and *vice versa*, has been described by the writer. Jour. Appl. Micros. 1899, **1**, 51.

REAGENTS.

The following reagents comprise all that are needed for practical work. Others which are useful in special investigations are described in Strasburger's and Zimmerman's works. (See Bibliography, p. 19.)

Acetic Acid. Glacial or 99 per cent acetic acid diluted with 2 parts of water.

Alcohol. In dehydrating preparations for mounting in xylol balsam, absolute alcohol is used, but for preserving, hardening, and most other purposes ordinary 95 per cent alcohol meets every requirement.

Alcanna Tincture. Macerate 20 grams of alkanet root for several days with 100 cc. of water. Dilute with an equal volume of water as used.

Ammonia Water. The concentrated solution containing about 30 per cent of ammonia gas is used in making Schweitzer's reagent and for some other purposes. For the turmeric test the concentrated solution should be diluted with 10 parts of water.

Canada Balsam in Xylol. The solution prepared ready for use may be obtained of all dealers in microscopic supplies.

Chloral Hydrate Solution. Dissolve 8 parts of chloral hydrate in 5 parts of water.

Chloroform.

Chlorzinc Iodine Solution. Treat an excess of zinc with hydrochloric acid, evaporate to a specific gravity of 1.8, and filter through asbestos. As needed, saturate a small portion of the sirupy liquid first with potassium iodide and finally with iodine.

The solution may also be prepared by dissolving 30 grams of zinc chloride, 5 grams of potassium iodide, and 0.89 gram of iodine in 14 cc. of water. The solution should be freshly prepared, and kept in a dark place.

Ether.

Ferric Chloride. Dissolve 1 part of the salt in 100 parts of water.

Fehling Solution. I. Dissolve 173 grams of crystallized Rochelle salts and 125 grams of caustic potash in water and make up to 500 cc. II. Dissolve 34.64 grams of crystallized copper sulphate in water and make up to 500 cc. Mix equal parts of I and II as needed.

Glycerine. For use as a mounting medium, dilute with an equal volume of water.

Glycerine Jelly (Kaiser's). Soak 1 part of finest French gelatine 2 hours in 6 parts of distilled water. Add 7 parts of glycerine, and to each 100 grams of the mixture, 1 gram of strongest carbolic acid. Warm for 10 to 15 minutes with constant stirring, until the flakes from the carbolic acid disappear. Filter through previously moistened glass wool. Warm as needed, and remove with a glass rod. Glycerine jelly is sold by all dealers.

Glycerine Gum. Dissolve 10 grams of gum arabic and 2 grams of glycerine in 10 cc. of water.

Hydrochloric Acid, Concentrated.

Iodine in Potassium Iodide. Dissolve 0.05 gram of iodine and 0.2 gram of potassium iodide in 15 cc. of water.

Iodine Tincture. Dissolve in 95 per cent alcohol sufficient iodine to make a light coffee-colored solution.

All iodine solutions deteriorate on keeping, particularly if exposed to the light.

Labarraque's Solution (chlorinated soda). Thoroughly triturate 75 grams of fresh chlorinated lime (bleaching-powder) with 600 cc. of water, added in two or three successive portions, and filter. To the filtrate add a solution of 150 grams of crystallized sodium carbonate in 400 cc. of water, mix thoroughly, warm if the solution gelatinizes, and again filter.

The solution gradually loses strength on standing, and should be kept in stoppered bottles in a cool, dark place.

Javelle Water (chlorinated potash) may be prepared in the same manner, substituting 58 grams of potassium carbonate for the sodium carbonate. This reagent is used for the same purpose as Labarraque's solution.

Millon's Reagent. Dissolve metallic mercury in an equal weight of concentrated nitric acid and dilute with an equal volume of water. The solution should be freshly prepared.

Nitric Acid, Concentrated.

Olive Oil.

Paraffine.

Phoroglucin Tincture. Dissolve 0.1 gram in 10 cc. of 95 per cent alcohol. The solution deteriorates on keeping.

Potash Solution. Dissolve 5 grams of caustic potash (potassium hydrate) in 100 cc. of water. If desired, caustic soda may be substituted for caustic potash.

The term "alkali" as used in this work refers to one or the other of these solutions.

Safranin Solution. Prepare a saturated water solution, and dilute as needed.

Schultze's Macerating Mixture. Mix a few crystals of potassium chlorate with concentrated nitric acid immediately before using.

Schweitzer's Reagent ("ammoniacal copper solution," "cuprammonia," "cuoxam"). Precipitate cupric oxyhydrate from a solution of copper sulphate by adding a slight excess of caustic soda or ammonia, filter and thoroughly wash. Dissolve the moist precipitate in strong ammonia with the aid of heat, cool, and filter from the precipitate which forms. It should be freshly prepared, and kept in the dark.

Soda Solution. Five per cent solution of caustic soda (sodium hydrate) may be substituted for potash solution as a clearing agent. In the crude-fiber process, and for removing dark coloring matters, 1¼ per cent solution is used.

Sulphuric Acid. The concentrated acid is employed in several tests. It should be diluted to 1¼ per cent for use in the crude-fiber process.

Turpentine (spirits or oil of turpentine).

Xylol.

COLLECTIONS.

A collection of the vegetable materials used as foods or food adulterants and mounts of such materials are as indispensable to the food microscopist as is an herbarium to a systematic botanist. Many points of structure and special reactions can be learned with the aid of such collections which cannot be properly described in words or illustrated by figures.

Standard Materials. The collection should include not only the fruits, seeds, barks, leaves, rhizomes, flowers, and other whole materials, but also the various products prepared from them. Many of these may be obtained from grain dealers, grocers, seedsmen and pharmacists, others may be collected in the field or garden. Powders are conveniently stored in screw-top bottles, which have the advantage over glass- or cork-stoppered bottles that they more completely exclude dust. Fruits, vegetables, and other succulent materials are preserved in alcohol or formaldehyde. Especially useful is the collection of economic seeds prepared under the direction of Frederick V. Coville, Botanist of the United States Department of Agriculture, by Gilbert H. Hicks, also the cabinet of materia medica specimens supplied by Parke, Davis and Company, Detroit, Mich., U. S. A.

Microscopic Mounts. Powders such as flour, meal, and starch are best mounted in water as occasion demands, but sections and other difficultly prepared specimens should be at hand in permanent form. The collection of mounts may be prepared either by the microscopist himself, or by a skilled worker from material of his selection. At present suitable collections of mounts are not on the market

PREPARATION OF MATERIALS FOR EXAMINATION.

MECHANICAL PREPARATION.

Cross-sections. In studying standard material cross-sections are indispensable, as they show the number and arrangement of the cell layers and certain details of structure. Longitudinal and tangential sections are of lesser importance. Sections are also useful in the examination of coarsely ground commercial products, such as ground coffee and other materials containing fragments large enough for cutting. It should be remembered, however, that sections play a comparatively unimportant rôle in diagnosis, as most of the materials which the microscopist is called upon to examine are fine powders and other preparations in which the tissues have been torn one from another, and can only be studied in surface view or as isolated elements.

Considerable discretion is required in the treatment preliminary to the cutting of sections. As a rule, dried materials are best cut after soaking in water for some hours or until thoroughly softened, although cruciferous seeds and some other materials are best cut dry. Succulent fruits and other fresh materials should be hardened in 50 per cent alcohol. Only in the investigation of very delicate tissues is it desirable to resort to the tedious process of impregnating with paraffine or collodion.

Large objects are held between the thumb and first finger during cutting, small objects between pieces of elder pith, sticks of soft wood, or in a hand vise, or else they are embedded in paraffine or glycerine gum. Wood for holding materials during cutting should be sawed across the grain into sticks so that the razor or microtome knife will cut with the grain.

Glycerine gum is used not merely to embed the object, but also to attach it to a piece of elder pith. The sections are cut after the gum has hardened.

Paraffine may be used not only for dry materials, whether or not impregnated with paraffine as described below, but also for fresh material or material softened in water, provided the outer surface is carefully dried to insure contact. It should have a melting-point of 54° or 74° C., and is conveniently molded into sticks by melting at the lowest possible temperature and pouring slowly into a glass or metal tube. The stick may be loosened from the tube by gentle heating. The object is introduced into a cavity in the end of the stick, and the paraffine melted about it with a hot wire or needle.

The section razor used for cutting soft objects should have a keen, thin edge, but for cutting nut shells and other hard tissues another razor with a beveled edge should be in readiness. Both are kept in order by honing and stropping.

The microtome is a convenience but not a necessity, being used almost exclusively in preparing permanent mounts for the collection or in difficult investigations. Many food microscopists use only a razor.

Impregnating and Embedding with Paraffine or Collodion is best carried out with material preserved while fresh in 50 per cent alcohol, although dry material may be soaked in water until the tissues are softened and then transferred to 50 per cent alcohol. To facilitate the process, seeds and small fruits should be cut in half, and other materials in as small pieces as practicable.

In carrying out the paraffine process the object is immersed successively in the following: 65, 80, and 95 per cent alcohol, absolute alcohol, a mixture of equal parts of xylol and absolute alcohol, xylol, a mixture of xylol and paraffine (melting at 43° C.), 43° paraffine kept at 50°, and finally 54° paraffine kept at 60°. The time required for permeation in each of these varies, according to the size and nature of the object, from one to several days. Finally the object is removed from the paraffine to a suitable mold, covered with melted paraffine, and allowed to cool.

If the collodion process is followed, the object is treated with 50, 65, 80, and 95 per cent alcohol and absolute alcohol as above described, but is removed from the latter to absolute ether, then to a mixture of ether and collodion, and finally to pure collodion. It is then transferred to a paper mould, covered with collodion, and, when the latter has solidified, the whole is placed in 80 per cent alcohol, where the collodion in some hours forms a cartilaginous mass enveloping the object.

Sections of fruit stones and nutshells are cut with a fine saw and after being attached to a slide by hot Canada balsam are ground down to the desired thickness on a whetstone. They are finally mounted in balsam.

Surface Sections are useful in studying epidermal tissues, fruit and seed coats, and other cell aggregates forming distinct layers. They are much easier to prepare than cut sections. Dried materials should be soaked in water, after which the layers may usually be removed by scraping or stripping. The separation of the coats from very small seeds is often facilitated by soaking for some hours in dilute ($1\frac{1}{4}$ per cent) caustic soda. Boiling with dilute soda is sometimes desirable, particularly if the layers contain coloring matters which render them opaque. The epidermal layers of fruits can often be separated by plunging into boiling-hot water.

The bran coats of cereals, the seed coats of legumes, and oil seeds, and the various layers of spices and other materials may be studied in fragments picked out from the coarsely ground products with forceps or separated by sifting. Even in quite finely ground products one often finds large enough fragments for studying in surface view not only the characters of the individual cells, but also the arrangement of the cells in the layers.

The different layers in surface sections may become separated from one another or they may remain in their original position one on top of another. In the latter case it is often possible by careful focusing not only to study successively the layers, but also to determine their order of arrangement. This is greatly facilitated by noting in preparing the mount whether the outer or the inner surface is uppermost, and also by comparison with cross-sections. Some materials which have no very characteristic single layer can be identified by the combination of several cell layers and their order of arrangement.

Powders. Since the food microscopist is called upon to examine powders more often than any other class of products, he should familiarize himself with the microscopic characters of standard materials in powder form. Tissues in definite layers, such as epidermal cells, the bran coats of cereals, and the coats of various seeds, have much the same appearance in the ground material as in surface preparations; except that in fine powders the fragments are smaller, and radially elongated elements, such as the palisade cells of legumes and cotton seed, often fall on their sides, presenting the same appearance as in cross-section. Cells not in layers, such as make up the endosperm of cereals and the cotyledons of legumes, do not present a striking appearance in powder form, although the contents of their cells, being liberated by the rupture of the cell-walls, may be studied to advantage. Stone cells, vessels, and other detachable elements are also striking objects in powders.

Commercial Powders should first be examined under a simple microscope, either before or after separation into grades by sifting, and fragments picked out for subsequent examination under the compound microscope. Mounts representing the whole material should also be made. If the powder is too coarse for mounting directly, it may be reduced to an impalpable powder in an iron mortar, or a small portion may be crushed on the slide with a scalpel.

Special instructions for the examination of flour are given on p. 54, of cereal cattle foods on p. 59, of ground oil cakes on p. 171, and of ground spices on p. 497.

Pulps. The flesh of ripe fruits may be examined as a pulp, hard elements, such as vessels and stone cells, being especially distinct in such preparations. The same method is used for commercial jams, jellies, pastes, etc.

Maceration by Schultze's method is useful in reducing hard materials to a pulp, thus isolating the elements. The process consists in cautiously heating a small amount of the material in a capsule with concentrated nitric acid and a few crystals of potassium chlorate. As soon as the tissues are sufficiently disintegrated, the solution is diluted with water and the fragments washed thoroughly by decantation.

TREATMENT WITH REAGENTS.

Mounting in Water. Although water is usually regarded as an inert substance, it serves in microscopic work as the most important of all reagents; in fact, if we had no other we would still be able to carry on our work with reasonable success.

Water dissolves sugars, gums, certain proteids, and other cell-contents, and in addition swells and partially dissolves constituents of the cell-walls. Most of these soluble substances have no marked microscopic characters, whereas the insoluble constituents, including starch and calcium oxalate among cell-contents, and cellulose, lignin, suberin, and cutin of cell-wall constituents, occur in striking and often highly characteristic forms. For these reasons water is especially suited as a microscopic medium, although it cannot of course be used for permanent mounts.

In the water mount we first observe whether starch is present, and if so, note the characters of the grains. Addition of iodine solution differentiates the starch grain from other bodies. We next turn our attention to the other elements, particularly the tissues. Starch, if present in considerable amount, obscures the tissues, but can be converted into a paste and thus rendered transparent by heating the mount to boiling over a lamp, replacing the water lost by evaporation. This boiling, which takes the place of treatment with alkali, chloral, or other clearing agents, also renders the tissues more distinct by swelling the cell-walls.

Air bubbles may be removed from a section by soaking in a considerable amount of recently boiled water.

Treatment with Iodine colors the starch grains of water mounts blue, proteid matter yellow-brown, and cellulose, lignin, and other cell-wall substances various shades of yellow.

The solution in potassium iodide acts more rapidly than the tincture, coloring the starch grains a deeper shade of blue.

If the tincture is added directly to the dry or alcohol material, starch grains are colored brown-yellow, changing to blue on dilution with water.

Treatment with iodine and then with strong sulphuric acid colors cellulose blue, lignified, suberized, and cuticularized tissues yellow. Chlor-zinc iodine gives much the same color reactions as iodine and sulphuric acid, and is more convenient. The best results are secured if the preparation is first soaked in water.

Treatment with Oil Solvents. Products containing a large amount of fat, oil, or essential oil can be studied to advantage only after treatment with chloroform, ether, turpentine, or some other oil solvent. Sections may be soaked in the solvent in a covered watch-glass, and powders may be extracted on a filter or in a fat extractor. More convenient methods, provided subsequent treatment with reagents is not needed, are to mount the section or powder directly in turpentine, which dissolves the oil, or else in olive or almond oil which mix with the oil of the product. These methods are especially useful in the study of aleurone grains.

Clearing. *Alkalies* (potassium or sodium hydrate) are the most serviceable clearing agents for general use. The treatment may be performed on the slide either by mounting directly in dilute alkali or by adding a small drop of 5 per cent alkali to a water mount, or in the case of dark-colored tissues by boiling with $1\frac{1}{4}$ per cent caustic soda.

Alkali dissolves starch, proteids, various coloring matters and other cell-contents. It also swells the cell-walls, and to some extent expands compressed tissues.

Chloral Hydrate acts more slowly than potash and soda, but has the advantage that it does not distort greatly the tissues.

Labarraque Solution (chlorinated soda) and *Javelle Water* (chlorinated potash) are admirable reagents for bleaching tissues and expanding compressed cells. They are particularly adapted for sections, but owing to the difficulty of removing the bubbles, are less suited for powders. Sections should be soaked in the reagents (diluted if necessary) until the desired result is attained, and then washed in water and finally in very dilute acetic acid. They become so transparent by this treatment that staining with safranin or some other dye is usually essential.

Crude Fiber Method. This process serves not merely for the quantitative determination of crude fiber, but also for clearing the tissues for microscopic examination. After weighing the crude fiber a small quantity may be removed for examination without introducing a perceptible error in the subsequent determination of ash. The action is so energetic as to destroy delicate tissues; but is valuable in clearing stone cells and other sclerenchyma elements.

The process (which may be abbreviated if used merely for clearing) is as follows: Extract 2 grams of the finely ground material with ether, place in a 500 cc. Erlenmeyer flask, and add 200 cc. of boiling 1.25 per cent sulphuric acid. Loosely cover the flask, heat at once to boiling, and boil gently thirty minutes. Filter on a paper, wash with hot water, and rinse back into the same flask with 200 cc. of boiling 1.25 per cent sodium hydroxide solution nearly free from carbonate. After boiling, as before, for thirty minutes, collect the fiber on a weighed paper, thoroughly wash with hot water, and finally with a little alcohol and ether. Dry to constant weight at 100° C., and weigh. Deduct the amount of ash in the fiber, as determined by incineration, from the total weight.

Staining. Great numbers of stains have come into use for staining cell-walls and cell-contents.

Safranin, a stain strongly recommended by Strasburger, has the advantage over most other stains in that it differentiates very beautifully the tissues, and does not, like most coal-tar colors, fade in glycerine mounts. The best results are secured by soaking the section for some time in a rather dilute water solution. Overstaining, with subsequent removal of the excess with alcohol, is often advantageous.

Treatment with Other Reagents is carried on in a watch-glass, or on the slide, as occasion demands. In the latter case the material is either treated directly with a drop of the reagent, or it is first mounted in water, and a drop of the reagent is drawn under the cover-glass by means of a piece of filter-paper placed on the opposite side.

Sections of impregnated material are attached to a slide by means of Meyer's albumen fixative, then soaked in chloroform or xylol until the paraffine is dissolved, and finally treated with reagents and stains *ad libitum.*

Permanent Mounting. The technical microscopist, as well as the investigator, often has occasion to mount in permanent form objects of special interest. If the material contains a large amount of oil, or if it has been impregnated with paraffine, these should be removed by treatment with chloroform, xylol, or other oil solvent. Objects which have been cleared with alkali or Labarraque's solution should be washed thoroughly in water and finally in very dilute acetic acid. Most other reagents can be removed by water or alcohol. Staining is advisable if the tissues are both colorless and transparent, and is essential if Canada balsam is employed as the mounting medium. Air bubbles may be removed by boiling or allowing to soak in a considerable bulk of freshly boiled water. Slides and cover-glasses must be scrupulously clean and free from finger prints.

The process of mounting is quite simple. A suitable sized drop of the mounting medium is placed in the center of the slide, the object is transferred to this, and the cover-glass is placed in position by means of forceps. If too much of the medium is used, the excess is removed with a piece of filter-paper; if too little, more is added from one side. The mount is finally ringed with two or more coats of cement.

It is well to keep the slide on the turn-table not only during ringing, but also while mounting, thus facilitating the centering of both object and cover-glass.

Mounting in Glycerine. A mixture of equal parts of glycerine and water is the best single medium for our purpose, since wet objects may usually be mounted directly without staining or dehydrating, and can be removed at any time for further treatment with reagents.

The mounting is greatly facilitated by so gauging the size of the drop that it exactly fills the space beneath the cover-glass. If more is added, or an excess removed, care should be taken to clean thoroughly the slide about the cover-glass with a filter-paper, otherwise the cement will not stick to the glass. The mount should be ringed two or three times with a good cement, allowing it to dry at least 24 hours between the coats.[1]

Mounting in Glycerine Jelly requires less skill than mounting in glycerine, but the heating necessitated by the process injures some materials,

[1] The writer uses "King's Transparent Cement" for the first coat, and "King's Lacquer Cell and Finish" (red or blue) or "White Zinc Cement" for the finishing coats, the three colors being used to distinguish respectively cross, surface, and longitudinal sections.

and, furthermore, the objects are not so readily removed should occasion demand.

A small cube of the solid or a drop of the melted jelly is placed on the slide and heated gently until fluid throughout. The object, which may be taken from water or glycerine, is then introduced, and the cover-glass, previously warmed to prevent introduction of air bubbles, is placed in position. After cooling, the excess of the jelly should be carefully removed, and the mount ringed, as described for glycerine mounts.

Mounting in Canada Balsam can be carried out only with objects freed from water. Dehydration is effected by soaking in 95 per cent alcohol, absolute alcohol, and finally in xylol, chloroform, or oil of cloves. Staining is essential for objects with colorless tissues.

A drop of the xylol balsam is placed in the center of the slide, the object is introduced, and the whole is covered with a slightly warmed cover-glass. More balsam is added if, after standing, the space under the cover-glass is not entirely filled. After the balsam has thoroughly hardened, the excess may be removed and the mount ringed with colored cement; this, however, is not essential, for the mount is permanent without it.

BIBLIOGRAPHY.[1]

BEHRENS: Guide to the Microscope in Botany (Trans. by Hervey). Boston, 1885.
CHAMBERLAIN: Methods in Plant Histology. Chicago, 1901.
LEE: The Microtomist's Vade Mecum. Philadelphia, 1900.
STRASBURGER and HILLHOUSE: Handbook of Practical Botany. London, 1900.
ZIMMERMANN: Botanical Microtechnique (Trans. by Humphrey) New York, 1901.

[1] Works in English.

THE PRINCIPAL HISTOLOGICAL ELEMENTS.

TISSUES.

Parenchyma (Fig. 1) is a general term for the simpler forms of tissues, with thin walls composed usually of cellulose. The common types of parenchyma cells are either isodiametric or somewhat elongated, and may or may not have intercellular spaces at the angles. If the walls are

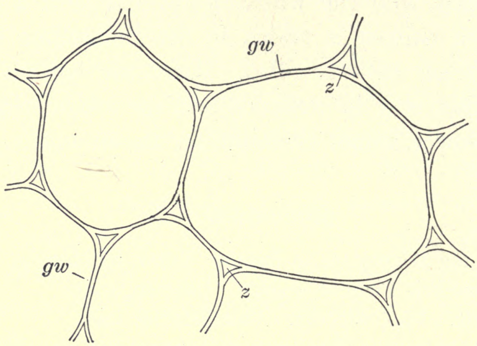

FIG. 1. Parenchyma from the stem of maize. *gw* double wall between two cells; *z* intercellular space produced by splitting of the double wall. (SACHS.)

of cellulose, chlorzinc iodine colors them blue and Schweitzer's reagent dissolves them.

Spongy Parenchyma (Fig. 2) is a loose spongy tissue with numerous intercellular spaces of considerable size.

Collenchyma (Fig. 3) is characterized by conspicuous thickenings at the angles of the cells. The cell-wall is composed of cellulose, or a modification known as collenchym. This form of tissue occurs most commonly in subepidermal layers.

Sclerenchyma includes a great variety of tissues with thickened walls composed chiefly of lignin. The walls of these cells as first formed are pure cellulose, lignin being deposited on the inner surface of the walls during subsequent growth. Chlorzinc iodine colors the walls yellow or yellow-brown; phloroglucin and hydrochloric acid, pink; aniline sulphate, deep yellow.

Stone Cells (Fig. 4) are isodiametric, or moderately elongated sclerenchyma elements, with thickened walls and conspicuous pores. They occur either singly or in groups in parenchyma, or form dense tissues, such as the shell of the cocoanut and the stone of the peach.

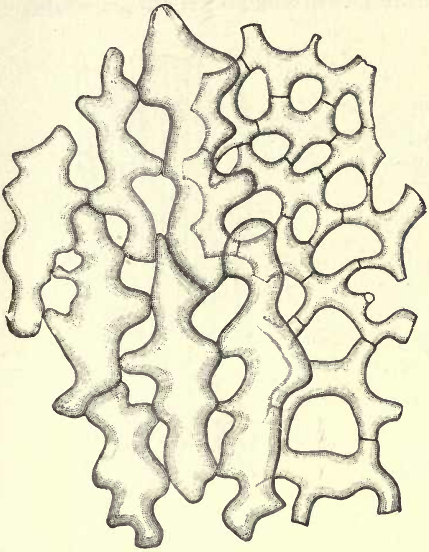

FIG. 2. Spongy Parenchyma from the hull (spermoderm) of the common pea. (MOELLER.)

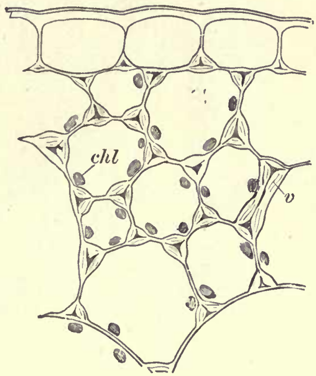

FIG. 3. Epidermis and Collenchyma from the petiole of *Begonia*. *v* thickened wall of collenchyma; *chl* chlorophyl grains. (SACHS.)

Sclerenchyma Fibers (Fig. 5) occur in various parts of plants. Those found in fibro-vascular bundles are known as *Bast Fibers*.

Other sclerenchyma tissues are found in stems, leaves, the coats of fruits and seeds, and in various organs.

Epidermal Tissues have certain characteristics peculiar to their position. They are usually covered by a membrane known as the "cuticle," composed of cutin, a substance related to lignin and suberin. Wax, silica, calcium carbonate, and calcium oxalate also occur as epidermal incrustations.

Stomata are made up of peculiarly differentiated epidermal cells. (See pp. 28–30.)

Hairs and Glands, including many beautiful and characteristic forms, are unicellular or multicellular outgrowths of epidermal layers.

Cork Cells form protective layers on stems and other parts. The cells are arranged in radial rows, and are polygonal in surface view, quadrilateral in section. Suberin, the characteristic constituent, is repellent of water.

Fibro-vascular Bundles (Figs. 6 and 25). The conducting elements of plants are commonly grouped into vascular or fibro-vascular bundles, of which the nerves of leaves and the strands of stems and roots are examples.

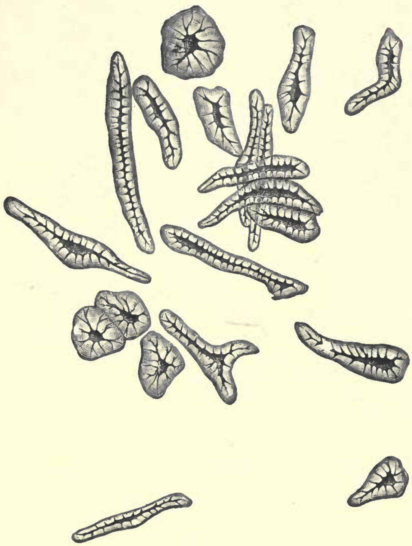

FIG. 4. Stone Cells from the shell of the cocoanut. (WINTON.)

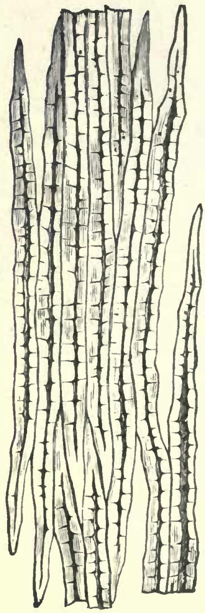

FIG. 5. Bast Fibers from the bark of *Sambucus nigra*. (VOGL.)

A bundle is made up of two distinct parts: (1) the xylem, wood or hadrome, consisting of vessels, tracheids, and other lignified elements, and (2) the phloem, bast or leptome, consisting of sieve tubes, cambiform cells, and other non-lignified elements.

Groups of bast fibers usually accompany the bundles.

For details as to the arrangement of xylem and phloem see pp. 39–45.

The Vessels of the xylem, also known as ducts and tracheæ, are thin-walled tubes with annular, spiral, scalariform or reticulated thickenings, or thick-walled tubes with pits or pores.

Tracheids resemble vessels in their markings, but consist of rows of cells placed end to end, not open tubes.

Sieve Tubes, the characteristic elements of the phloem, are thin-walled, elongated cells, with perforated transverse partitions known as sieve plates. These sieve plates also occur to some extent on the longitudinal walls. Both the sieve tubes and the accompanying cambiform cells are composed of cellulose.

Bast Fibers (Fig. 5) are long, pointed cells with lignified walls. Pores through which pass diagonal, crossing fissures are usually evident.

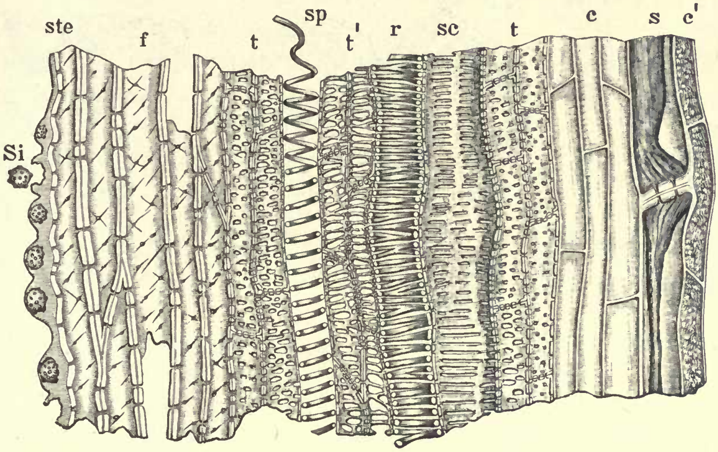

FIG. 6. Fibro-vascular Bundle from the mesocarp of the cocoanut, in longitudinal section. *ste* stegmata; *Si* silicious body; *f* bast fibers; *t* tracheids with small pits; *t'* tracheids with large pits; *sp* spiral vessel; *r* reticulated vessel; *sc* scalariform vessel; *s* sieve tube; *c* and *c'* cambiform cells. (WINTON.)

Latex Tubes (Fig. 341). These are branching tubes containing milky secretions, found in various stems and roots, and occasionally in fruits.

CELL-CONTENTS.

Protoplasm, the living matter of the vegetable cell, includes: (1) cytoplasm, which in the growing stage is a viscous, stringy, more or less granular substance, but in the dried material has no marked characters; (2) the cell nucleus, a rounded body differentiated by staining and often evident without; and (3) the plastids or chromatophores, including the chloroplasts, leucoplasts, and chromoplasts.

Chloroplasts, or chlorophyl grains, occur in all green parts, and play an important rôle in assimilation (p. 29.)

Leucoplasts are inconspicuous, colorless bodies instrumental in the formation of starch (p. 644).

Chromoplasts are orange or yellow bodies of various shapes to which certain organs owe their distinctive color.

Proteids occur either in amorphous form or as aleurone grains. On heating with Millon's reagent they form a reddish deposit; on treatment with iodine solution they are colored yellow or brown.

Aleurone Grains (Fig. 7) are found in the perisperm, endosperm, and embryo of seeds, particularly oil seeds, and like starch grains have marked

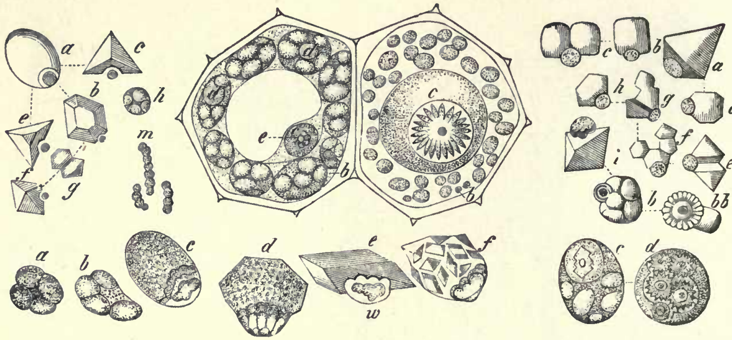

FIG. 7. Aleurone Grains; in the center two cells filled with aleurone grains. (T. HARTIG.)

microscopic characters, which are often characteristic of the species or genus. These grains vary in size from less than 1 μ to over 50 μ. Among the numerous shapes are round, oval, irregularly swollen, angular, and warty forms. They are colored yellow or brown by iodine solution and take up readily certain aniline dyes, hæmatoxylin, and other stains.

Being partly soluble in water, they should be mounted either in glycerine after extraction of the oil in which they are often embedded, or directly in oil or turpentine. Each grain consists of a ground substance, in which are usually embedded one or more crystalloids, one or more globoids, and often a crystal rosette of calcium oxalate, the whole being inclosed in a thin membrane.

1. The ground substance consists of amorphous proteid matter, and is usually soluble in water, although after previous standing in alcohol it dissolves slowly. It is also soluble in dilute alkali, acids, and various reagents, but is not affected by oil or oil solvents.

2. Crystalloids are proteid crystals belonging to the isometric or hexagonal system. In some species they are so large that a single crystalloid makes up the bulk of the grain, in others they are very minute. For the most part they are insoluble in cold water, but dissolve in very dilute alkali (less than 1 per cent), dilute acetic or hydrochloric acid. They are insol-

uble in saturated solution of picric acid (distinction from globoids) and in saturated solution of sodium phosphate (distinction from all other constituents of the grains).

3. Globoids, according to Pfeffer, consist of lime and magnesia combined with phosphoric acid and an organic acid. They are usually globular, of uniform transparent structure, and are not colored by iodine solution. They are insoluble in both cold and hot water, but unlike crystalloids are soluble in saturated solutions of picric acid and sodium phosphate and insoluble in dilute potash.

4. Calcium oxalate occurs as single crystals or as crystal rosettes. These are insoluble in water, alkali, and acetic acid, but dissolve readily in dilute hydrochloric acid.

Alkaloids are nitrogenous substances, often with marked stimulating or toxic properties. Some, such as morphine and piperine, are crystalline solids, others, such as nicotine, are liquids. Caffein and theobromin are often classed as alkaloids.

Starch. See pp. 643–650.

Sugars occur in solution in certain stalks, roots, and fleshy fruits, and in the form of crystals in dried fruits. Crystals are readily seen in alcohol or glycerine mounts of raisins, figs, dates, etc.

Cane-sugar crystallizes in monoclinic prisms. It does not reduce Fehling solution.

Invert-sugar consists of equal parts of dextrose and levulose, and is formed by the splitting up or "inversion" of cane-sugar. In many fruits both cane- and invert-sugar are present, although as a rule the large fruits contain much more cane-sugar than the small fruits. As both dextrose and levulose are reducing sugars, they are detected by heating the dry object to boiling in a drop of Fehling solution diluted with two drops of water. The red precipitate of copper suboxide thus formed is often evident to the naked eye.

Other sugars occurring in plants are rafinose, mannit, dulcit, melitose, etc.

Inulin is a water-soluble carbohydrate found in the roots of the dandelion and other composite plants. In alcohol material it forms sphærocrystals; in dried material, colorless, irregular lumps.

Gums. These include various mucilaginous substances, some of which are formed in the cell, others are derived from the cell-walls. They swell in water and are precipitated by alcohol.

Glucosides are compounds of sugars with organic acids. Some of them, such as hesperidin, form needle-shaped crystals insoluble both in water and dilute acids.

Tannins are themselves colorless, but are usually associated with brown coloring substances. In the fresh material they are in solution, but on drying they impregnate the tissues or form brown deposits. With iron salts they become dark blue or green.

Fats and Fatty Oils rank with carbohydrates and proteids in importance. They occur in all parts of the plant, but are especially abundant in certain seeds, where they serve as reserve material. The fats may form amorphous masses, or beautiful crystals, while the oils occur as globules. Both are soluble in ether, chloroform, benzine, turpentine, and xylol, and form soaps with alkalis. With few exceptions they are insoluble in alcohol. On treatment for some hours with alcanna tincture, all fatty substances, as well as resins and essential oils, take on a beautiful red color.

Waxes are closely related to fats.

Essential Oils and **Resins** are formed in glands or secretory cavities, and are distinguished from fats and fatty oils by their solubility in alcohol.

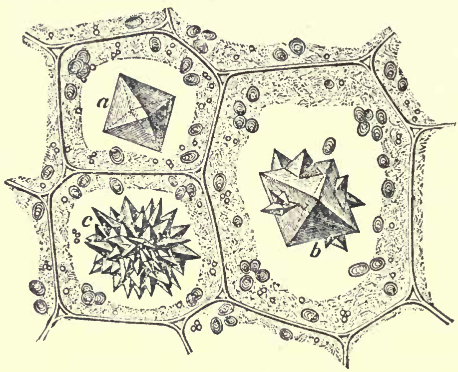

FIG. 8. Crystals of Calcium Oxalate. *a* large single crystal; *c* crystal rosette or cluster; *b* intermediate form. (KNY.)

Calcium Oxalate. Lime is one of the elements essential for plant growth, its chief function being to render poisonous oxalic acid harmless by conversion into insoluble calcium oxalate. Monoclinic, or rarely tetragonal, crystals of this salt occur in certain tissues, and are often of great service in diagnosis. Four distinct forms deserve special mention: (1) crystal clusters or rosettes (Fig. 8, *b* and *c*), (2) large single crystals (Fig. 8, *a*), (3) raphides or needle-shaped crystals (Fig. 9), and (4) crystal sand or deposits of numerous minute crystals (Fig. 10).

Calcium oxalate is distinguished from all other crystalline substances by its insolubility in water, alkali, and acetic acid, its solubility without

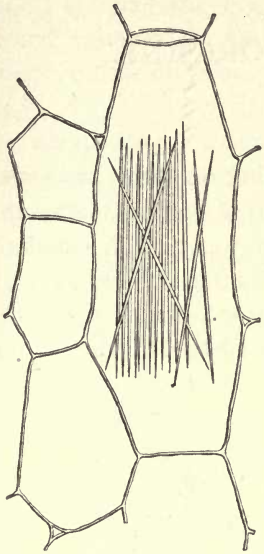

FIG. 9. Raphides of Calcium Oxalate from the flesh of the pineapple. (WINTON.)

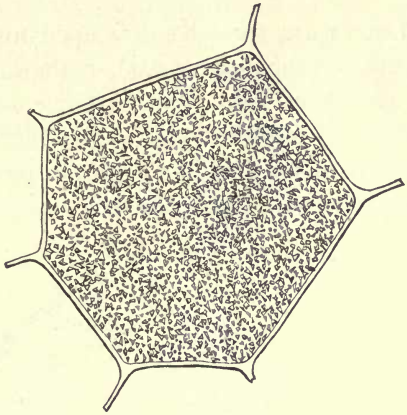

FIG. 10. Crystal Sand of Calcium Oxalate from the leaf of belladonna. (WINTON.)

effervescence in dilute hydrochloric acid, and the formation of crystals of calcium sulphate with sulphuric acid.

Calcium Carbonate is present in certain plants as concretions or cystoliths (Fig. 169, *cy*), less often as crystals. It dissolves in dilute hydrochloric acid with effervescence.

Silica forms an incrustation on certain epidermal tissues, and less often occurs as warty bodies in peculiar cells known as stegmata (Fig. 6, *Si*).

BIBLIOGRAPHY.[1]

DE BARY: Comparative Anatomy of the Vegetative Organs of the Phanerogams and Ferns (Trans. by Bower and Scott). London, 1884.

GOODALE: Physiological Botany. I. Outlines of the Histology of Phænogamous Plants. New York, 1885.

STRASBURGER, NOEL, SCHENCK, and SCHIMPER: A Text-book of Botany (Trans. by Porter and revised by Lang). London, 1903.

[1] Works in English.

MORPHOLOGY OF ORGANS.

THE LEAF.

Leaves are specially developed for carrying on three processes: (1) assimilation (photosynthesis), or the formation of organic matter through the agency of light from carbonic acid and water, with exhalation of oxygen; (2) respiration, or the oxidation of organic matter, with exhalation of carbonic acid; and (3) transpiration, or exhalation of water drawn up from the soil. As a rule they expose a large surfaee to the air, and have

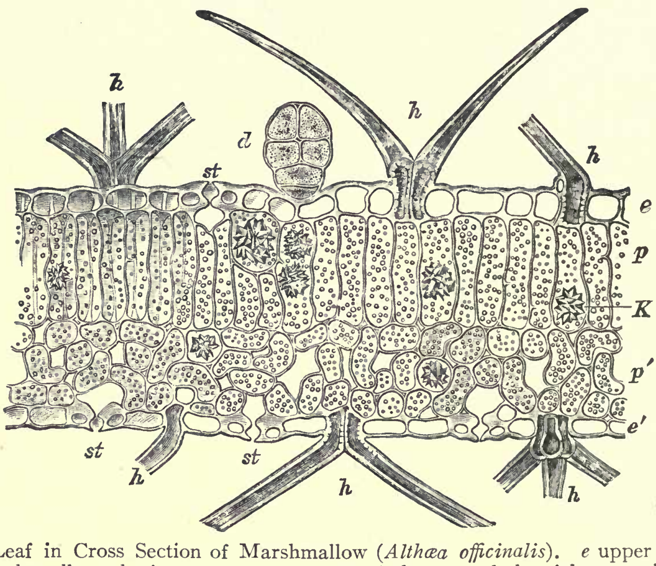

Fig. 11. Leaf in Cross Section of Marshmallow (*Althæa officinalis*). *e* upper epidermis; *p* palisade cells and *p'* spongy parenchyma of the mesophyl; *e'* lower epidermis; *h* hairs; *d* glandular hairs; *st* stomata; *K* calcium oxalate rosette. (Vogl.)

special adaptations for facilitating or preventing communication with the air, according to the needs of the plant.

A cross-section of a leaf (Fig. 11) shows that it is made up of a middle layer or mesophyl of green tissues with a network of veins, between two colorless cuticularized epidermal layers.

The Lower Epidermis (Fig. 12) consists of ground cells interspersed with stomata, and often with hairs or glands. The ground cells in surface view differ greatly in character according to the species. Some are sharply polygonal, or quadrangular, with straight walls, others have ill-defined angles and wavy walls, and others still are irregular in outline. The walls may be thin or thick, porous or non-porous; the cuticle smooth or wrinkled.

Stomata are slits between two hemi-elliptical guard cells, which when open allow free access of air to the mesophyl. In some leaves two or more modified cells, known as accompanying cells, adjoin the guard cells. The

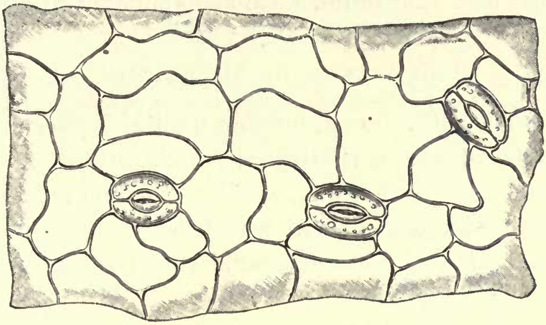

FIG. 12. Epidermis with Stomata from the leaf of *Hydrangea Hortensia*, in surface view. (MOELLER.)

guard cells of the stomata are the only cells of the epidermis containing chlorophyl grains.

In addition to ordinary or air stomata a larger form known as water stomata occurs on some leaves.

Hairs and Glands (secretory hairs) present an endless variety of beautiful and characteristic forms. All hairs whether unicellular or multicellular are epidermal outgrowths, but *Emergences* are made up of tissues belonging both to the epidermis and the mesophyl.

The Mesophyl in the under part of the leaf forms a spongy parenchyma, (Fig. 11, *p'*) thus facilitating assimilation, respiration and transpiration, but in the upper part it is a close tissue, often consisting of one or more layers of palisade cells (*p.*).

Chlorophyl grains are present in all the mesophyl cells, but are most abundant in palisade cells of the upper layers (Fig. 11, *p*). They are rounded bodies varying up to 12 μ in diameter. They consist of granules (some green, others colorless), proteid matter and starch grains, embedded in a ground substance and surrounded by a membrane. During assimilation starch is continually being formed in these grains, but is soon dissolved and translocated to other parts of the plant. In dried leaves the chlorophyl grains are more or less brown in color, and lack distinct characters.

The Fibro-vascular Bundles of leaves are strongly developed in the midribs and main branches, but in the smaller branches are rudimentary. Spiral vessels are particularly abundant. Other elements which may occur in the mesophyl are stone cells, crystal cells, resin cavities, oil cells, latex tubes, etc.

The Upper Epidermis may or may not be similar to the under epidermis in structure, but as a rule stomata are less abundant or absent.

Preparation of Materials.

Sections are cut with a razor, holding the leaf between pieces of pith. In the case of thin leaves it is advisable to cut into several strips, place one on the other, and section all together. Pieces of the epidermis are readily stripped off from moist leaves with forceps. In powdered leaves the elements are isolated by squeezing under the cover-glass.

THE FLOWER.

Although the four parts of the flower—sepals, petals, stamens, and pistils—are metamorphosed leaves, usually only the sepals, less often both sepals and petals, resemble leaves in outward appearance and structure.

Calyx. The sepals, like leaves, consist of mesophyl between two epidermal layers. Stomata and often hairs are developed on one or both epidermal layers. The mesophyl parenchyma usually contains chlorophyl, but a well-developed palisade layer is seldom present. Bundles are more or less strongly developed.

Corolla. The petals are of various colors and commonly of delicate texture. Each consists of two epidermal layers and a middle tissue of elongated parenchyma (corresponding to the chlorophyl parenchyma of leaves) through which pass delicate bundles. Stomata are usually lacking, but hairs and papillæ are often present. Spiral vessels, and less often crystal fibers, are present in the bundles. The coloring matter of the fresh petal is usually dissolved in the cell-sap, seldom in the form of chromoplasts. The perfume of flowers is due to essential oils present in the cell-sap, in special cavities (nectaries), or in glands

Stamens. Each consists of a slender, cylindrical (less often flattened, leaf-like) filament, bearing at the apex an anther with a pair of pollen sacs on each side of the central bundle (Fig. 13). On ripening, the sacs

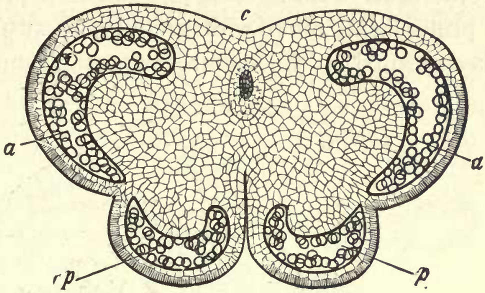

FIG. 13. Anther of *Datura Stramonium* in cross section. *c* connective tissue with fibro-vascular bundle; *a* outer pollen sacs; *p* inner pollen sacs. (FRANK.)

of each pair unite, and finally the wall opens by a slit or pore, liberating the pollen grains.

The walls of the anthers (Fig. 14) are composed of an outer layer

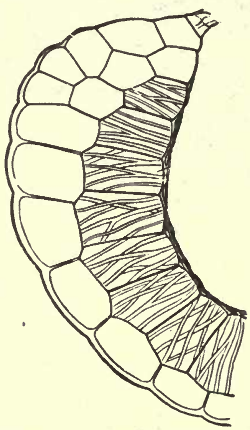

FIG. 14. Anther Wall in cross section showing the outer epidermis and the endothecium with reticulated walls. (SACHS.)

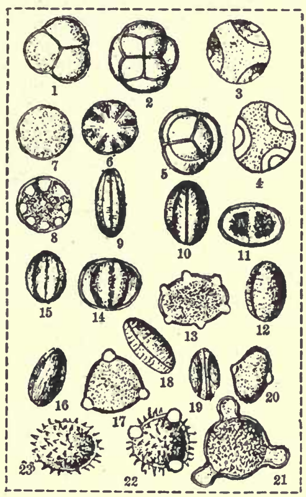

FIG. 15. Pollen Grains. 1, 2 heath; 3, 4 linden; 5 blueberry; 6, 7 marjoram; 8, 9 lavender; 10, 11 sage; 12, 13 balm; 14, 15 rosemary; 16, 17 flax; 18 white mullein; 19, 20 melilot; 21 willow herb; 22, 23 composite plants. (VILLIERS AND COLLIN.)

or epidermis, sometimes hairy, and an endothecium or inner layer of characteristic cells with narrow radial ribs forming reticulations.

Pollen Grains (Fig. 15) are mostly globular, rounded, or tetrahedral, either smooth or else covered with warts, bristles, or pits. They consist of single cells clothed with two membranes; the outer thick, forming a kind of cuticle; the inner thin, forming the cell-wall proper. The contents consist of protoplasm, often with granules in suspension. When the ripe pollen is deposited on the stigma the protoplasmic contents burst

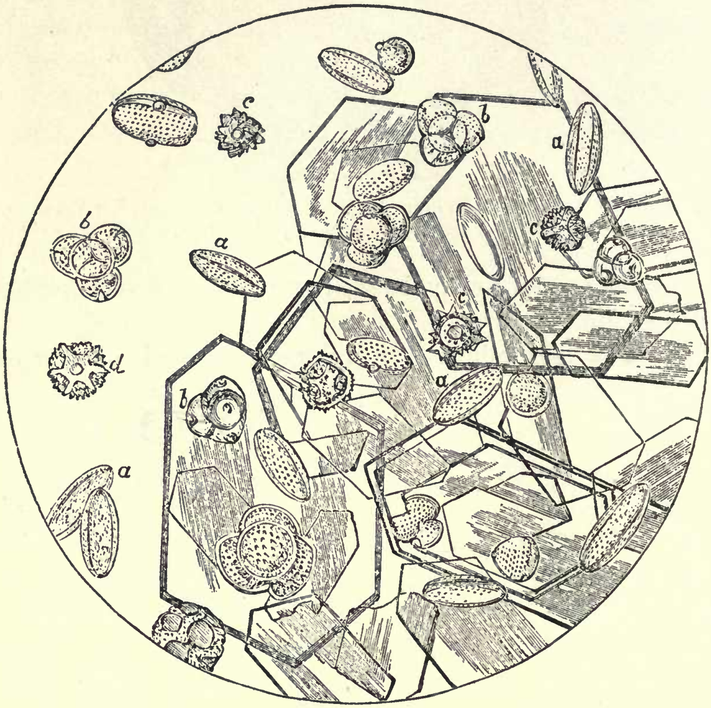

FIG. 16. Pollen Grains and Crystals of Cane-sugar irom Honey. *a* pollen grains of furze; *b* of heath; *c* of some composite flower. (HASSALL.)

out through clefts, or more commonly through pores, forming tubes which penetrate through the tissues of the stigma and style into the ovule, effecting fertilization. The shape, size, and markings of pollen grains are often so characteristic as to permit the identification of the species, not only in powders, but also in honey, thus furnishing evidence as to the flowers visited by the bee (Fig. 16).

The **Pistil** (Fig. 19) consists of stigma, style, and ovary, the latter enclosing the ovules. The stigma is clothed with clammy papillæ, on which the pollen grains lodge. The style is long or short, with a central channel. It is made up of elongated elements. The ovary walls are of quite simple structure, but the fruits into which they ripen are often complex.

THE FRUIT (PERICARP AND SEED).

A fruit in its simplest form is a ripened pistil, consisting of pericarp or matured ovary wall, and one or more seeds or matured ovules. In some fruits, notably the apple and other pomes, the fruit flesh is developed from

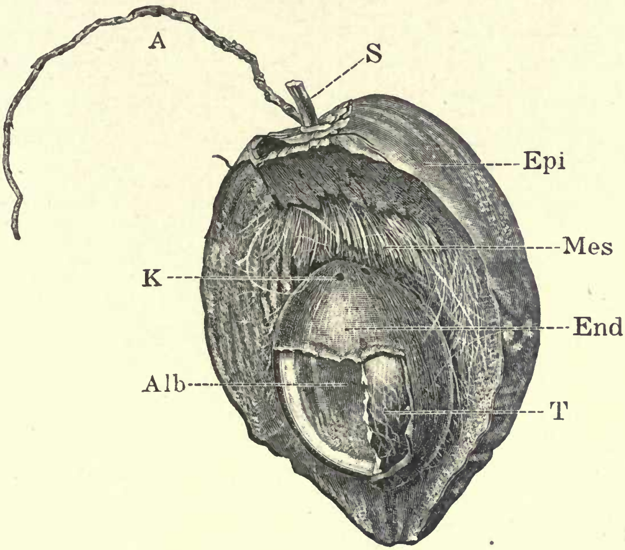

FIG. 17. Cocoanut Fruit. *S* lower part of axis forming the stem; *A* upper end of axis with scars of male flowers. Pericarp consists of *Epi* epicarp, *Mes* mesocarp with fibers, and *End* endocarp or hard shell; *T* portion of spermoderm adhering to endosperm; *Alb* endosperm surrounding cavity of the nut; *K* germinating eye. (WINTON.)

receptacle and ovary wall. If the flower has several ovaries, these on ripening form an aggregate fruit. A compound or multiple fruit consists of the united fruits of several flowers. The receptacle of aggregate and compound fruits is sometimes fleshy, forming the bulk of the fruit. Examples are the strawberry, an aggregate fruit with nutlets on the outside of a fleshy receptacle, and the fig, a compound fruit with nutlets on the inside of a hollow receptacle.

PERICARP.

The mature pericarp may be dehiscent (e.g. legumes, crucifers), or indehiscent, and in the latter case may be entirely fleshy (e.g. grape, banana, and other berries), entirely dry (e.g. acorn and other nuts), or partly fleshy and partly dry (e.g. peach and other drupes). It may be distinct from the seed or seeds (e.g. peach, legumes), or united with the seed (e.g. cocoanut, wheat, and other cereals).

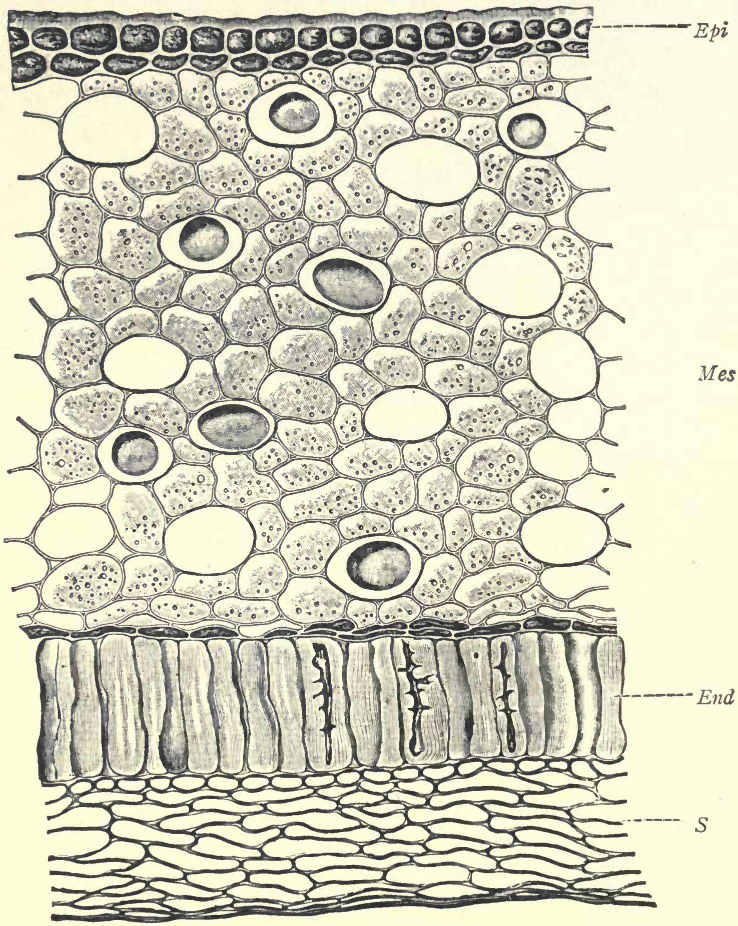

FIG. 18. Coats of Bayberry (*Laurus nobilis*) in cross section. Pericarp or fruit coat consists of *Epi* epicarp, *Mes* mesocarp, and *End* endocarp; *S* spermoderm, testa, or seed coat. (MOELLER.)

Since the pericarp is the ripened pistil and the pistil is a metamorphosed leaf, all three are analogous in structure, each consisting of a middle layer between two epidermal layers. The mesocarp, or middle layer of fruits, is often however more complex in structure than the mesophyl of leaves.

The Epicarp (Figs. 17 and 18, *Epi*), or epidermis of the pericarp, consists of a single layer of cells, often interspersed with hairs and rarely with stomata.

The Mesocarp (Figs. 17 and 18, *Mes*) in some fruits forms a layer several centimeters or even decimeters thick, in others is scarcely thicker than a sheet of writing-paper.

The hypoderm, consisting of one or more layers adjoining the epicarp, is often different in structure from the layers further inward.

The remainder of the mesocarp may be homogeneous throughout except for fibro-vascular bundles, or may consist of several forms of cells (stone cells, oil cells, etc.) irregularly distributed in a homogeneous ground tissue, or arranged in distinct layers. The visible cell-contents include starch, sugar, oil, tannin, chlorophyl, calcium oxalate, and other substances.

The Endocarp (Figs. 17 and 18, *End*), strictly speaking, consists of the innermost cell-layer, but in the case of nuts, dupes, and other fruits the hard shell made up of numerous layers of stone cells is commonly designated by this term.

SEED.

In order to understand the structure of the seed it is essential to consider the structure of the ovule from which it was developed, and the changes this undergoes after fertilization.

An ovule (Fig. 19) consists of the body or *Nucellus* (*s*) in which is embedded the *Embryo sac* (*t*), the whole being enclosed by one, or more often two, coats or *Integuments* (*p*, *q*) with an opening at one end known as the *Foramen* (*m*). The *Chalaza* (*o*) is the base of the ovule where the integuments unite with the nucellus: the *Hilum* is the place of attachment with the support or *Funiculus*. In orthotropous and campylotropous ovules the chalaza is also the hilum, in anatropous and amphitropous ovules they are more or less separated, and are joined by a ridge known as the *Raphe* (*n*).

The pollen grains soon after they are deposited on the stigma of the flower send off tubes (*klm*) which penetrate through the style into the cavity of the ovary, and through the foramen into the nucellus, finally entering the embryo sac and effecting fertilization. As a result of this fertilization the *Embryo* and the *Endosperm* are formed in the embryo sac, and these together with the *Perisperm*, consisting of the developed, or more commonly, degenerated nucellus, the *Spermoderm*, consisting of the matured integuments, and occasionally certain appendages, make up the seed.

Either the embryo, the endosperm or the perisperm of the mature

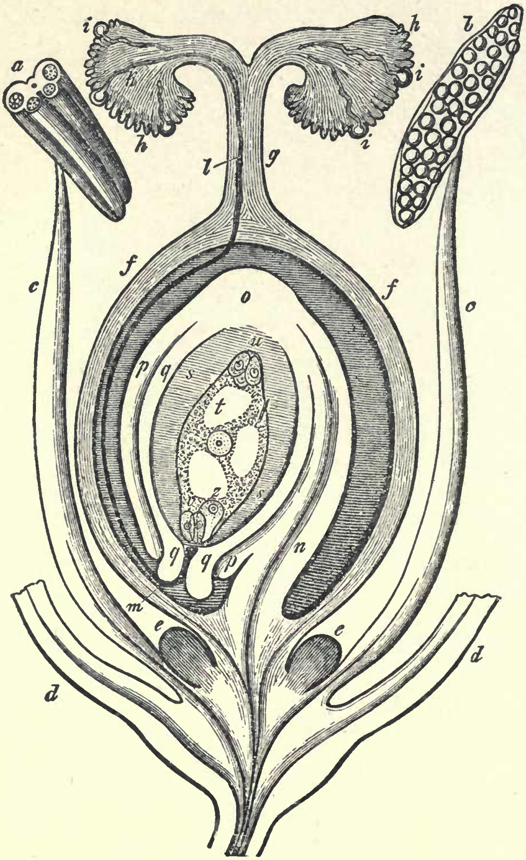

FIG. 19. Flower of Simple Type in Longitudinal Section.

Stamens consist of *c* filaments and *a*, *b* anthers (*a* cross section, *b* after dehiscence showing pollen grains).

Pistil consists of *h* stigma with *i* pollen grains sending off tubes, one of which (*klm*) has reached and penetrated the ovule, *g* style, and *f* ovary, the walls of which later develop into the pericarp.

Ovule consists of *n* funiculus (below) and raphe (above), *o* chalaza, *p* outer integument, *q* inner integument, *m* micropyle, *s* nucellus or body of the ovule, and *t* embryo sac in which, through the agency of *u* antipodal cells, *v* synergidæ, and *z* oosphere, are developed the endosperm and the embryo.

d bases of sepals; *e* nectaries. (SACHS.)

seed may form the chief reservoir of reserve material, or, on the other hand may be reduced to a rudiment.

This reserve material may consist chiefly of starch (e.g. cereals), of oil (e.g. cottonseed, linseed), or of cellulose (e.g. coffee, ivory nut).

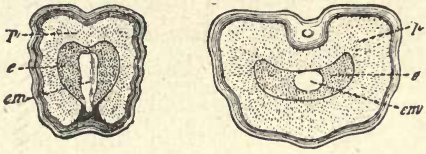

FIG. 20. Cardamom Seeds. *A* longitudinal section, ×3. *B* transverse section, ×5. *p* perisperm; *e* endosperm; *em* embryo. The reserve material in the perisperm is largely starch; in the endosperm and embryo it is oil and proteids. (LUERSSEN.)

The Spermoderm, Testa, or **Seed Coat,** includes all the layers developed from the integuments of the ovule.[1] It may be simple or complex, thin or thick, soft or hard. In some seeds it consists of but one or two thin layers (e.g. cereals), in others of five or six distinct layers, some of the layers being several cells thick (e.g. cucurbits). Among the common elements are thick- and thin-walled palisade cells, stone cells, crystal cells, spongy parenchyma, and ordinary parenchyma. The "Nutritive Layer" found in some seeds is a parenchymatous tissue containing in the early stages of development reserve material, but later forming an ill-defined tissue of empty compressed cells.

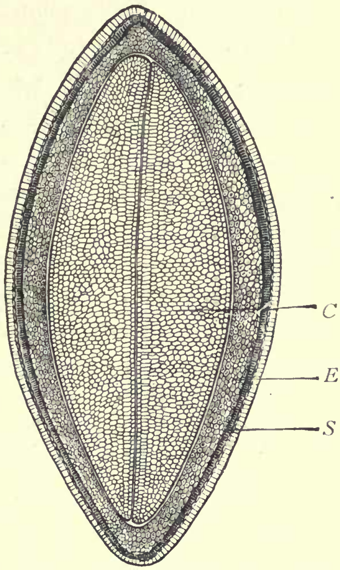

FIG. 21. Linseed in cross section. *S* spermoderm or seed coat; *E* endosperm; *C* cotyledons. The reserve material, consisting of oil and proteids, is partly in the endosperm and partly in the embryo. (MOELLER.)

The hilum, chalaza, and raphe of the ovule preserve their characters in the seed, while the foramen becomes more or less indistinct, forming the *Micropyle.*

The raphe (present in anatropous and amphitropous seeds) is a bundle of vascular elements with more or less distinct branches.

The appendages of the Spermoderm include the *Arillus* or seed mantle,

[1] Some authors apply the term "testa" only to that portion of the seed coat developed from the outer integument of the ovule, the portion developed from the inner integument (if present) being termed "tegmen." This usage leads to confusion owing to the difficulty of tracing the origin of each layer.

an outgrowth from the hilum, the *Arillode*, an outgrowth from the micropyle, and the *Caruncle*, a wart-like body formed on the micropyle, also bristles, wings, and other appendages which aid in disseminating the seeds.

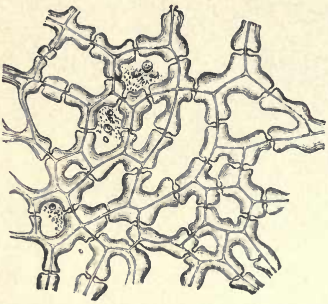

FIG. 22. Endosperm of Date Stone with reserve material in the thickened cell walls. (MOELLER.)

The Perisperm or **Nucellar Tissue** is usually a thin layer, often without cell structure, but in black pepper and cardamom (Fig. 20, *p*) it forms the larger part of the seed and contains the store of reserve starch.

The Endosperm constitutes the bulk of many seeds (e.g. cereals), but is almost entirely absent in others (e.g. bean, crucifers). In the cereals the outer layer or layers of the endosperm consist of aleurone cells, the remainder, of starch cells; in linseed the endosperm (Fig. 21, *E*), which constitutes about half of the seed, contains aleurone grains and oil, but no starch; in coffee and the date stone (Fig. 22) the bulky endosperm contains reserve material in the form of thickened cell-walls.

The Embryo is a young plant with *Cotyledons* or seed leaves, *Radicle* or young root, and *Plumule* or bud. It may be embedded in the center or one side of the endosperm (e.g. cereals, coffee), or it may constitute the bulk of the seed (e.g. legumes, crucifers, cottonseed). In the latter case the reserve material, which may be largely starch or oil, is located chiefly in the thickened cotyledons and radicle (Fig. 23).

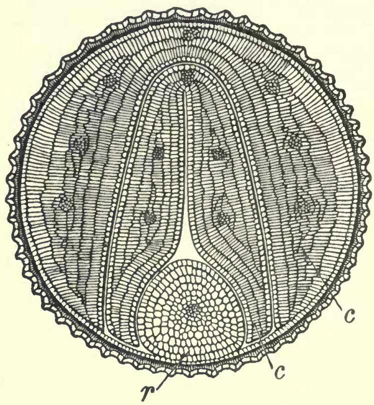

FIG. 23. Mustard Seed in cross section. Embryo consists of *c* folded cotyledons and *r* radicle. Reserve material, consisting of oil and proteids, is entirely in the embryo. (TSCHIRCH.)

THE STEM (BARK AND WOOD).

The stem is the axis connecting the leaf and root systems. It may be aerial or subterranean, simple or branched, herbaceous or woody. In some herbaceous plants it is exceedingly short, the leaves appearing to spring directly from the root, while in many herbaceous and all woody plants it consists of an elongated trunk with or without a system of branches.

Not only does the stem serve to mechanically support the leaves, but also, by means of the bundles, to distribute over the plant solutions of salts absorbed by the roots, of carbohydrates assimilated by the leaf, and of other organic substances formed in various parts of the plant. During the resting season large amounts of reserve material are stored in stems.

AERIAL STEMS.

The fibro-vascular bundles of phenogamous stems are collateral, that is, the phloem and xylem of each are in the same radial plane. Usually the phloem is entirely on the outer side of the xylem, but in some stems it is partly on the inner side (bicollateral).

In the stems of exogenous plants (dicotyledons and gymnosperms) the bundles with the parenchyma separating them are arranged in a zone between the pith and the cortex. The outer ring of the bundle zone contains the bast fiber groups, the middle ring, the phloem groups, the inner ring, the xylem groups. If the plant is perennial a ring of active cells or cambium soon forms between the phloem and xylem rings, adding each year new tissues to the inner side of the former and the outer side of the latter. The layers outside of the cambium constitute the bark, those between the cambium and pith constitute the wood.

The bundles of endogenous plants (monocotyledons) are irregularly distributed through a parenchymatous ground tissue. There is no cambium and no differentiation into bark and wood.

The following descriptions of annual and perennial stems apply only to exogenous plants:

Annual Stems.

The stems of herbaceous plants and the young stems of woody plants consist of at least four distinct zones:

1. *Epidermis.* This resembles the epidermis of the leaf. Stomata and hairs are often present.

2. *Cortex.* The tissue is largely parenchyma, often with outer layers of collenchyma and inner layers containing either bast fibers or stone cells, or both.

3. *Endodermis.* This consists of a single layer of cells with thin but suberized walls. Starch grains are usually found in the cells.

All the tissues inside of the endodermis form the central cylinder or *Stele.*

4. *Bundle Zone.* The *Phloem* strand of each bundle consists of sieve tubes, cambiform cells, and parenchyma; the *Xylem* strand, of vessels (tracheæ), tracheids (distinguished from vessels by the cross partitions), and parenchyma. The bundles are separated from each other by parenchyma, developing in perennial stems into the medullary rays. Groups of bast fibers are commonly present in the outer parenchyma, or *Pericycle.*

5. *Pith.* This consists entirely of typical parenchyma.

PERENNIAL (WOODY) STEMS.

The structure of perennial stems (Figs. 24 and 25) is much more complicated than that of annual stems, owing to the formation of secondary bark and wood by the cambium, also of cork and secondary cortex by the phellogen.

The **Bark** includes all the outer part of the stem up to the wood. It is readily stripped off from the latter, especially during the spring, the separation being through the delicate cells of the cambium. Although many barks are used in medicine (e.g. cinchona, slippery elm, cascarilla), and in the arts (e.g. oak, hemlock), only cinnamon and its substitutes are of importance as foods.

1. *Cork.* With the increase in diameter of the stem the epidermis is ruptured and finally disappears entirely. In its place cork is formed by an active (meristematic) layer known as the *Phellogen.* As the cells of the phellogen divide by tangential partitions, the rectangular cork cells, as seen in cross sections, are in radial rows. They usually have suberized walls, and often contain dark contents with the reactions of tannin.

As the stems continue to grow the primary cork often suffers the same fate as the epidermis, and is replaced by a secondary layer formed in the cortex by a new phellogen. This secondary cork may later be replaced by a tertiary, and so on.

2. *Secondary Cortex*, a thin-walled tissue hardly distinguishable from the primary cortex, is formed from the phellogen on the inner side.

3. *Primary Cortex.* The parenchymatous ground tissue often contains starch and crystals of calcium oxalate. Stone cells and bast fibers may also be present. The endodermis of old stems is not usually distinguishable from the other layers.

4. *Pericyle.* This may consist of parenchymatous ground tissue with

isolated groups of bast fibers, or of a "mixed ring" composed chiefly of stone cells and bast fibers.

5. *Bast.* Like the phellogen, the cambium forms one kind of tissue on the outside, another kind on the inside. These are respectively the phloem and the xylem, a layer of each being produced each year. The phloem layers of different years' growth, together with the separating

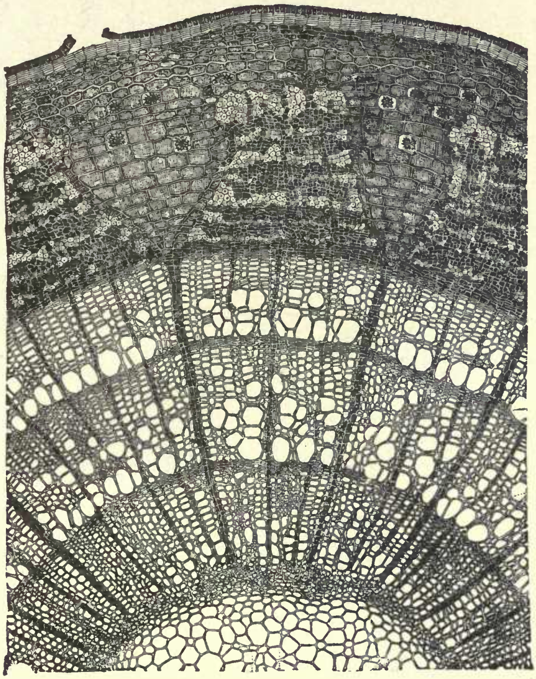

FIG. 24. Branch of the Linden, in cross section, showing the bark and three annual layers of wood. (KNY.)

partitions or medullary rays, form the bast ring. In addition to sieve tubes, cambiform cells, and parenchyma, the bast may contain oil cells, mucilage cells, latex tubes, and other elements. Starch is often present.

Microscopic Elements of Barks. The elements of chief importance in diagnosis are bast fibers, stone cells, starch grains, and cork. The other elements have less striking characters.

Wood. The wood elements, like the phloem elements, are in radial rows, separated by medullary rays, and also in annual layers. The elements include vessels and tracheids of numerous types, wood fibers, parenchyma, and medullary parenchyma. The parenchyma cells often contain starch and calcium oxalate, and all the tissues may contain or be impregnated with resins, essential oils, etc.

Woods are not used as foods, but sawdust and red sandalwood powder are common adulterants.

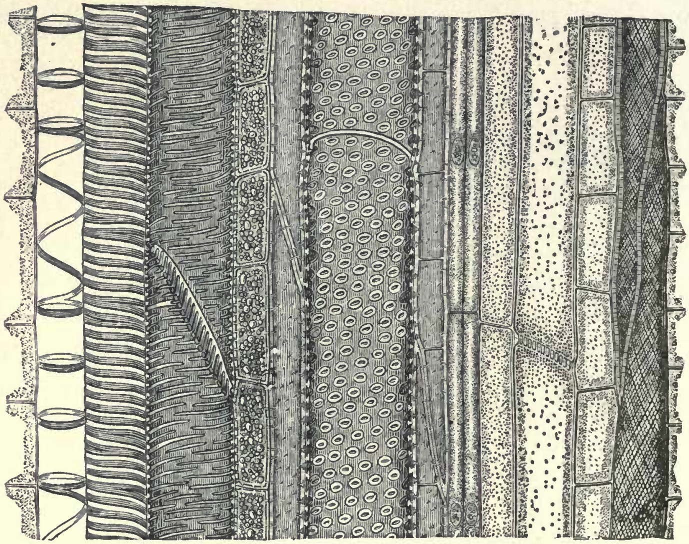

FIG. 25. Elements of a Dicotyledonous Fibro-vascular Bundle in longitudinal section. *a* parenchyma of pith; *b* annular vessel passing into spiral vessel; *c* spiral vessel; *d* reticulated vessel; *e* wood parenchyma; *f* wood fiber; *g* pitted vessel; *h* wood parenchyma; *i* cambium layer; *k* cambiform cells; *l* sieve tubes; *m* sieve parenchyma; *n* bast fibers; *o* parenchyma. (KNY.)

The Microscopic Characters of woods of angiosperms and gymnosperms as given by Moeller are as follows:

The Wood of Angiosperms is characterized by the vessels with numerous small pits (Fig. 26, *g*). More abundant than these are the wood fibers (*l*) occurring mostly in bundles, accompanied often by wood parenchyma (*p*), and crossed by medullary parenchyma (*m*). Simple crystals of calcium oxalate in crystal fibers occur in many tropical woods (Fig. 28, *k*).

Determination of the species or even the genus by the characters of the powder is very difficult. Chief dependence must be placed on the structure of the vessels.

The Wood of Gymnosperms consists in large part of tracheids with single rows of bordered pits (Fig. 27, *t*), which, except in the spring wood, where they occur sparingly, are on the sides adjoining the medullary rays. These are most striking in radial sections. Well-formed oxalate crystals are absent. The wood of certain European species may be distinguished by the characters of the medullary rays.

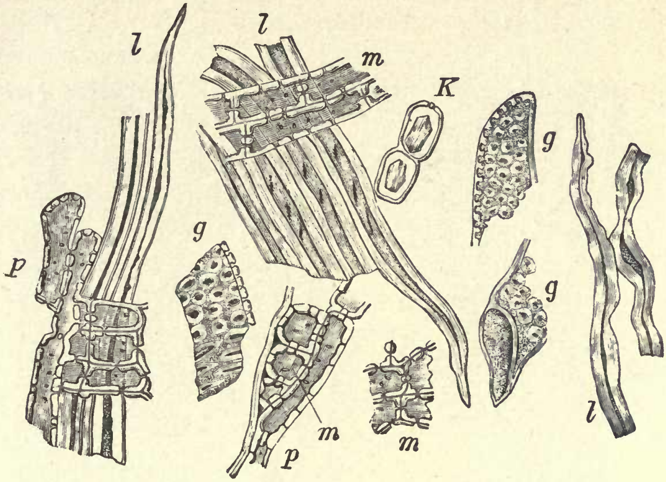

FIG. 26. Sawdust of an Angiospermous Wood. *p* wood parenchyma; *l* wood fibers; *g* vessels with numerous pits; *m* medullary rays in radial and tangential view; *K* crystal cells. ×160. (MOELLER.)

SUBTERRANEAN STEMS.

To this class belong *Rhizomes* or root-stalks (e.g. ginger), *Tubers* (e.g. potato), and *Corms* (e.g. cyclamen). Rhizomes in common parlance

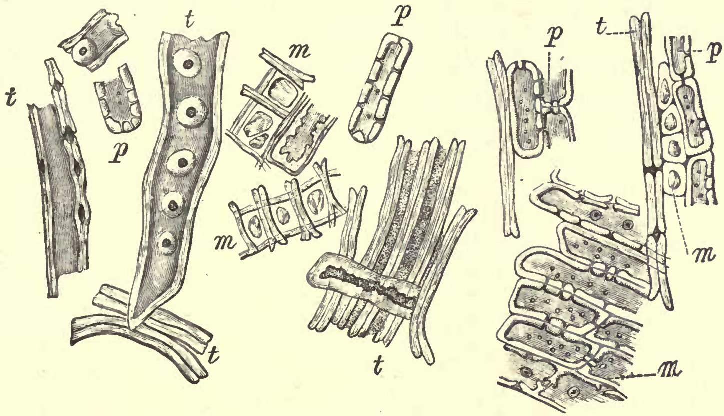

FIG. 27. Sawdust of a Coniferous Wood. *t* tracheids with single rows of pits; *m* medullary rays; *p* parenchyma. ×160. (MOELLER.)

are classed with roots. *Bulbs* (e.g. onion) are subterranean stems covered with leaf scales.

Many subterranean stems are reservoirs of starch, sugar, inulin, and other reserve materials, and are important foods. Their tissues are much

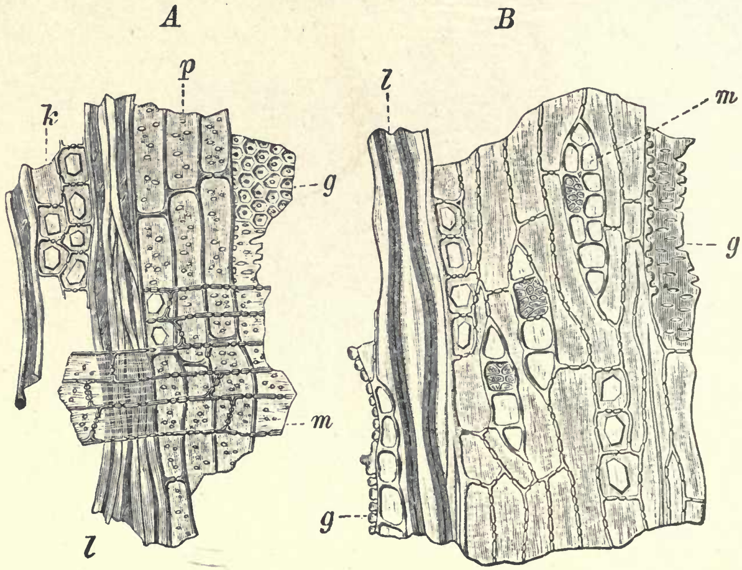

FIG. 28. Red Sandalwood (*Pterocarpus santalinus*). *A* radial section; *B* tangential section. *k* crystal fibers; *l* wood fibers; *p* wood parenchyma; *g* bundle; *m* medullary rays. ×160. (MOELLER.)

simpler than those of aerial stems, consisting chiefly of parenchyma with a thin covering of cork and relatively few bundles. In the rhizomes of dicotyledons the bundles, like those of aerial stems, are collateral; in those of monocotyledons they start as collateral, but later often become concentric, with the xylem encircling the phloem. Mechanical elements, being unnecessary, are usually few or entirely lacking.

THE ROOT.

The root fixes the plant in the soil and absorbs the water and mineral matters essential for life and growth. In certain plants the root is fleshy, serving as a storehouse for reserve material. The roots used as foods include the turnip, beet, carrot, parsnip, chicory, and others.

ANNUAL ROOT.

The general structure resembles that of dicotyledonous stems, but the elements of the epidermis and the arrangement of the bundles are quite different.

1. *Epidermis.* Root hairs, consisting of blunt, thin-walled outgrowths from the center of epidermal cells, are found on young roots. Hairs such as occur on aerial parts, as well as stomata, are never present.

2. *Cortex.* This is a parenchyma tissue similar to that of stems. Chlorophyl is absent.

3. *The Endodermis* is characterized by the suberized and often thickened walls.

4. *Bundle Zone.* The outer layer (pericycle or pericambium) is of parenchyma. The bundles proper are of the radial type the phloem and xylem being side by side, not one in front of the other, as in the collateral bundles. The groups of xylem and phloem elements alternating with one another form a chain about the center of the root.

5. *Pith.* This may or may not be evident.

Certain fleshy annual roots, such as the beet, show concentric rings similar to those of wood. These are formed by a series of new cambium layers which appear one after another in the parenchyma, each producing a ring of phloem and xylem.

Perennial (Woody) Roots.

The secondary changes in the roots of monocotyledons are not important, but in dicotyledons the structure finally becomes much the same as that of the stem. The epidermis with root hairs is replaced by cork, and the bundles change from radial to collateral. The cambium forms outside of the xylem and inside of the phloem of each bundle, and consequently is at first sinuous in cross section. As the thickening proceeds the radial arrangement disappears, and the cambium finally forms a ring like that of stems.

BIBLIOGRAPHY.

See p. 27.

PART II.

GRAIN: ITS PRODUCTS AND IMPURITIES.

GRAIN.

Grain, in the ordinary acceptance of the term, includes such fruits of the cereals (*Gramineæ*) and buckwheats (*Polygonaceæ*) as are valuable as food for man and cattle.

The impurities of grain include weed seeds, ergot, spores of smuts, straw, dirt, and other matters (p. 145 *et seq.*). Weed seeds belonging to the *Gramineæ* and *Polygonaceæ* are described with the economic species of these families.

The nature and purity of grain is readily determined by macroscopic examination, although a thorough understanding of the microscopic structure of the whole grain is essential for the diagnosis of products.

Flour and Meal.

In the examination of mill products with respect to their purity and wholesomeness, the following points call for consideration: (1) Is added mineral matter present? (2) Is it or has it been infested by insects or other forms of animal life? (3) Has the product or the grain from which it was made been damaged by rusts, moulds, or bacteria? (4) Was it made from sprouted grain? (5) Are starch or tissues of weed seed present in appreciable amount? (6) Are foreign flours or other vegetable adulterants present?

Mineral Adulterants. Calcium sulphate (gypsum), calcium carbonate (chalk), clay, and even sand were formerly added to flour and meal, but at the present time are seldom if ever used in any cereal product, although calcium sulphate in considerable amount has been frequently detected in cream of tartar and baking-powder, and powdered rock (talc and tremolite) to the extent of 25 per cent has been found in one brand of baking-powder examined at the Connecticut Experiment Station.

Foreign mineral matter is best detected by determinations of ash, supplemented by an ash analysis, although the chloroform test (p. 53) furnishes valuable indications.

Insect and other Animal Contamination. According to Chittenden[1] the insects which most commonly infest grain and flour are cosmopolitan, having been distributed by commerce to all quarters of the earth. The following common species are described:

The granary-weevil (*Calandra granaria* L.), the rice-weevil (*Calandra oryza* L.), the Angoumois grain-moth (*Sitotroga cerealella* Ol.), the wolf-moth (*Tinea granella* L.), the Mediterranean flour-moth (*Ephestia Kuehniella* Zell.), the Indian (maize) meal moth (*Plodia interpunctella* Hbn.), the meal snout-moth (*Pyralis farinalis* L.), the confused flour-beetle (*Tribolium confusum* Duv.), the rust-red flour-beetle (*Tribolium ferrugineum* Fab.), the slender-horned flour-beetle (*Echocerus maxillosus* Fab.), the broad-horned flour-beetle (*Echocerus cornutus* Fab.), the small-eyed flour-beetle (*Palorus ratzeburgi* Wissm.), the yellow meal-worm (*Tenebrio molitor* L.), the dark meal-worm (*Tenebrio obscurus* L.), the saw-toothed grain-beetle (*Silvanus surinamensis* L.), the red or square-necked grain-beetle (*Cathartus gemallatus* Duv.), the European grain-beetle (*Cathartus advena* Waltl.), and the cadelle (*Tenebroides mauritanicus* L.)

Among the creatures found only in the ground products are the sugar-mite (*Lapisma saccharina*), the common flour-mite (*Acarus farinæ*), and the feathered mite (*Acarus plumiger*).

The figures and descriptions given by Chittenden, Böhmer,[2] and other authors aid in the identification of the foregoing species.

In cases where the live insects are no longer present evidences of previous infection are often furnished by the wings or other parts of dead insects, also by the excrement, webs and other remains, seen either with the naked eye or under the microscope.

Wheat is often infested by the wheat-worm (*Tylenchus scandens* Schu., *Anguillula tritici* Need.) a nematode related to Trichina. So-called "cockle-wheat" (Fig. 29) consists of wheat kernels entirely transformed by the ravages of this disgusting, but probably harmless, creature. The more or less distorted kernels are from 3–7 mm. long, and often forked at the apex. The tough shell, consisting of rather thick-walled porous sclerenchyma elements with intercellular spaces, inclose a tangled mass of worms, which, as may be seen with a low power, become active when thrown into water. The worms are upward of 1 mm. long, pointed at

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[1] Some insects injurious to stored grain. U. S. Dept. Agr. Farmer's Bulletin No. 45, Washington, 1896.

[2] Kraftfuttermittel, pp. 65–68.

both ends, and appear to be filled with a granular substance. They are easily recognized in water mounts.

The Cryptogamic Plants which attack the inflorescence of cereals often render the grain unfit for flour-making. To this class belong the smuts (p. 165) and ergot (p. 164).

Molds, yeast plants, algæ and bacteria are also developed in the flour itself, especially after exposure to dampness, and as a consequence the

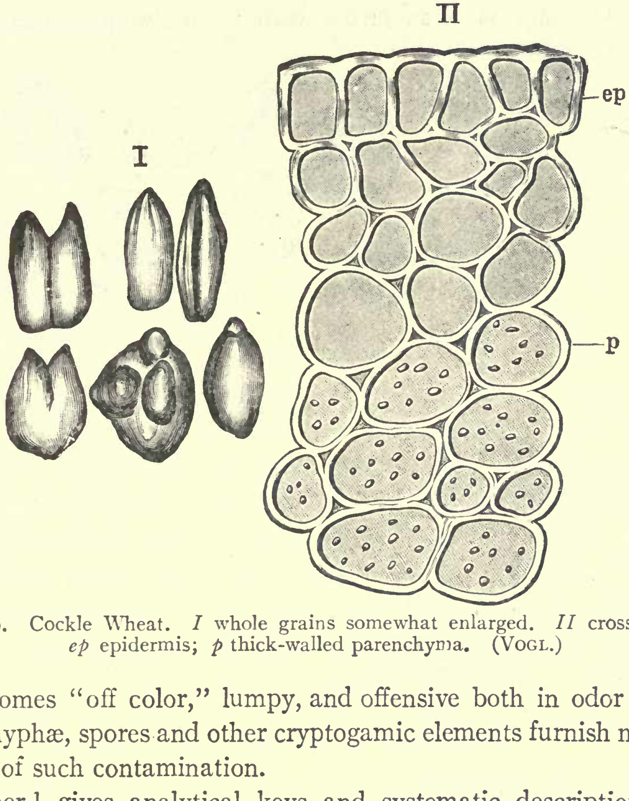

FIG. 29. Cockle Wheat. *I* whole grains somewhat enlarged. *II* cross section: *ep* epidermis; *p* thick-walled parenchyma. (VOGL.)

flour becomes "off color," lumpy, and offensive both in odor and taste. Fungus hyphæ, spores and other cryptogamic elements furnish microscopic evidence of such contamination.

Böhmer[1] gives analytical keys and systematic descriptions for the identification of these and other microorganisms.

Sprouted Grain. As a consequence of improper storage, grain sometimes begins to sprout, and thus loses in a greater or less degree its value for flour-making. Under the microscope the starch grains have a characteristic appearance due to their partial solution by the diastatic ferments developed during germination. The concentric rings are unusually dis-

[1] Loc. cit.

tinct, and branching channels resembling burrows of worms occur in many of the grains (Fig. 30).

Weed Seeds. See pp. 145–163.

Foreign Flour. In Europe, wheat flour is sometimes adulterated with rye, barley, buckwheat, rice, bean, potato, or acorn flour, while in America it is frequently mixed with maize flour.

Rye flour, according to the German authorities, is much oftener adulterated by inferior wheat flour than wheat flour by rye flour.

Buckwheat flour is often mixed with wheat, maize, barley, or rice

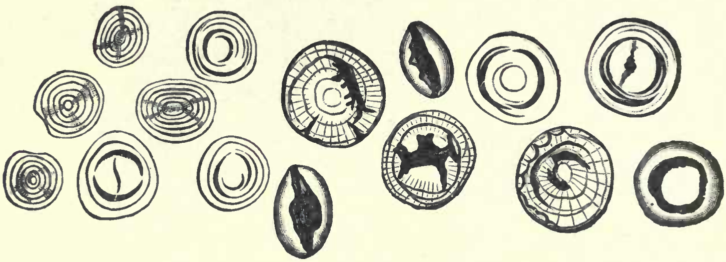

FIG. 30. Starch Grains from Sprouted Cereals. Left, large grains from wheat; right, from rye. (VOGL.)

flour, sometimes with the intent of cheapening the product; less often to meet the demands of consumers.

Rice flour is liable to the same forms of adulteration as buckwheat flour, while maize flour, because of its cheapness, is seldom adulterated.

Sawdust, Maize Cob, and other similar waste products cannot be reduced to a sufficiently fine powder to be used in fine flour, but are sometimes mixed with coarse meal, and cattle foods. They are detected by their high percentage of crude fiber and low percentage of starch and protein, as well as by their characteristic tissues.

METHODS OF EXAMINATION.

Preliminary Examination. The color, odor, taste, and other physical characters should first be noted and compared with samples of known purity. Flour or meal that is damp, mouldy, foul-smelling, or infested by insects, is obviously unfit for food whatever may be the results of chemical or microscopic examination.

Color Test. In German mills and custom-houses since 1894, the color of flour has been determined by "pekarizing" (pekarisiren) as follows:[1]

[1] Vereinbarungen zur einheitlichen Untersuchung u. Beurtheilung von Nahrungs- u. Genussmittel. Berlin II, 1899, 18.

Spread two teaspoonfuls (15–20 grams) of the flour on a glass plate or thin board, so as to form a parallelopiped 5 cm. long, 3 cm. broad and 2 mm. high. Cover with a glass plate and press until the surface is smooth.

In this way the color of different samples may be much more accurately compared than when loose.

The differences in color are brought out still more strikingly by carefully placing the plate in a slightly inclined position under water and keeping in that position for about one minute.

Caillettet's Chloroform Test, designed chiefly to furnish indications of mineral adulteration, consists in shaking in a test-tube about 2 grams of the flour with 25 cc. of chloroform. If on standing, any considerable amount of deposit collects at the bottom of the tube, the presence of mineral matter is indicated, as the flour particles, being for the most part lighter than chloroform, rise to the surface.

This residue may be examined chemically, but the test should always be corroborated by an accurate determination of ash in the original material and an analysis of the ash.

Beneke's Chloroform Test.[1] This test serves not only to detect mineral powders but also to distinguish rye flour from wheat flour, or to detect the presence of one in the other. It is as follows: Place 100 grams of the flour in a 500–600 cc. flask and add enough chloroform to fill the flask two thirds full; cork and shake carefully until no lumps remain; then fill nearly full, shake vigorously, and allow to stand. A brown deposit of dirt soon settles, and gradually a further deposit, consisting largely of aleurone cells forms a layer over the last. After about 24 hours, this latter deposit should be examined with the naked eye and under the microscope, noting especially the color. The aleurone cells of rye are blue or olive-green, those of wheat yellow-brown.

Vogl's Alcohol-Hydrochloric Acid Test[2] furnishes indications of the presence of foreign flour or ground weed seed.

Shake violently 2 grams of the flour in a test-tube with 10 cc. of a solution containing 5 per cent of hydrochloric acid and 70 per cent of alcohol; warm finally at a gentle heat and allow to settle. Note the color in reflected light of the column of solution, the meniscus, and the deposit.

Wheat flour entirely free from impurities yields both a colorless solution and a colorless deposit, and wheat flour with a small amount of im-

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[1] Landw. Vers.-Stat. 1889, **36**, 337.

[2] Die wichtigsten vegetabilischen Nahrungs- u. Genussmittel, p. 24.

purity, also common rye, oat, and barley flour, yield a pale yellow or pale yellow-red solution. A decided coloration of the solution, particularly at the meniscus, indicates a considerable amount of weed seed.

Cockle (*Agrostemma*) and darnel (*Lolium*) color the solution orange-yellow; leguminous seeds, rose-red, violet or purple; cow wheat (*Melampyrum*), blue-green or green; ergot, flesh-red to blood-red.

Gluten Test. Make a handful of the flour into a dough with the smallest possible amount of water and wash with continual kneading under a stream of water. Wheat flour yields by this treatment an elastic mass of gluten while the flour of other cereals is gradually but completely washed away.

Chemical Examination. Determination of the usual proximate constituents in the flour often aids in the diagnosis. For example, wheat flour is moderately rich in protein but poor in fat, corn flour is somewhat poorer than wheat flour in protein but much richer in fat, while buckwheat and rice flour are poor in both of these constituents.

Microscopical Examination. In 1882, the Association of German Millers offered a prize of a thousand marks for an essay describing a simple process for detecting admixtures in wheat and rye flour. Wittmack won this prize, and the motto of his essay was: "Das Mikroskop ist der beste Leitstern."

Not only is it true that the microscope is the most valuable means for the examination of flour, but in many cases it is the only means.

The following methods of preparing the material for examination will be found useful:

Direct Examination. The points of special importance are the size and shape of the starch grains, the presence or absence of aggregates, the size of the hilum, and the distinctness of the rings. With the aid of the key on p. 64 and the descriptions under each cereal identification of the group and often of the particular starch is readily accomplished. Among the more difficult problems are the distinction of the grains of wheat, rye, and barley; of rice, oats, and darnel; and of maize and sorghum.

Polarized light is useful in determining the locations and form of the hilum through which the crossed lines seen with crossed Nicols always pass. In cereal starches the hilum is central, and in potato and various other starches eccentric. The hilum of leguminous starches is elongated (see Fig. 572).

The crossed lines differ greatly in intensity, being scarcely evident in wheat, rye, and barley, but distinct in maize, sorghum, rice and many other kinds.

The brilliancy of the starch grains and their crosses when viewed with polarized light also aids in detecting them in the presence of fat globules and aleurone grains, although the addition of iodine solution accomplishes the same end.

Heating the water mount to boiling or *Addition of Alkali* (potassium or sodium hydrate) dissolves at once the starch and proteid matter and thus clears the tissues. Usually, however, this treatment, which is so valuable in the case of materials with considerable bran tissues, is of less service in the examination of flour than one of the following methods for *accumulating* the bran tissues from a large amount of the material.

Schimper's Scum Method.[1] Mix thoroughly 3 grams of the flour with 100 cc. of water and heat without further stirring until the boiling-point is reached. The scum which rises to the surface contains the greater part of the hairs and other bran tissues, and may be transferred to a slide and examined both directly and after treating with chloral or alkali.

Steinbusch's Diastase Method.[2] Make 10 grams of the flour into a paste with 40 cc. of water and add with constant stirring 150 cc. of boiling water. Cool to 55°–60° C. and add 30 cc. of malt extract (prepared by digesting at room temperature for 3 hours 1 part of freshly ground malt and 10 parts of water and filtering) and keep at 55°–60° for 15–30 minutes. Dilute, allow to settle, decant off the liquid, wash the residue once or twice by decantation, and finally treat with 1 per cent sodium hydrate.

This method is more laborious than the two following methods and has no advantage except in the case of delicate tissues. If quantitative determinations of starch are made, the residue after the malt digestion may be used for microscopic examination.

Hydrochloric-acid Method.[3] Mix 5 grams of the flour in a casserole with 500 cc. water, heat to boiling, add 5 cc. concentrated hydrochloric acid and boil for 15 minutes. After allowing to settle, decant off the super-

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[1] Schimper, Anleitung zur mikroskopischen Untersuchung der vegetabilischen Nahrungs- u. Genussmittel. Jena 1900, 17.

[2] Ber. d. deutsch. Chem. Ges. **14**, 2449.

[3] Various modifications of this method have been described by Moeller, Schimper, and other authors.

natant liquid and mount the deposit of bran elements either in water, chloral or dilute alkali.

Lauck's Method[1] is the same as the crude-fiber method (p. 17) except that 2.5 per cent sodium hydrate is used and the solution is boiled but 5 minutes.

The treatment dissolves completely the starch, proteids and fat, thus making the tissues very transparent, but it also distorts the hairs by swelling the walls, and for that reason is not suited for the detection of wheat flour in rye flour, or vice versa.

Of the processes for accumulating and clearing the tissues, Schimper's scum method has the least action on the cell-walls, Steinbusch's diastase method somewhat more, the hydrochloric-acid method still more, while Lauck's method is most energetic of all. The methods are arranged according to the intensity of their action.

Vogl's Naphthylene-blue Method.[2] Thoroughly mix 2 grams of the flour with a small quantity of a solution of 0.1 gram of naphthylene blue in a mixture of 100 cc. absolute alcohol and 400 cc. water. Transfer to a slide, allow to dry and examine in sassafras oil or some other essential oil or else in creosote or guaiacol. After this treatment the pericarp coats and contents of the aleurone cells and germ tissues appear bright blue or violet-blue, and the walls of the aleurone cells light blue, while the tissues and contents of the starch cells remain colorless and are rendered transparent by the mounting medium.

Bamihl's Test (p. 70).

BIBLIOGRAPHY.

See Bibliography of Wheat.

Bread.

Bread, in the broad sense of the word, including biscuit, cakes and other cereal oven products, is made either from the flour of one cereal or of several cereals. It is raised commonly either with yeast, baking-powder (or an equivalent), or eggs.

The examination of bread is much more difficult than that of flour, partly because other vegetable materials are present, and partly because the starch grains of the flour are much distorted by baking.

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[1] Vereinbarungen zur einheitlichen Untersuchung u. Beurtheilung von Nahrungs- u. Genussmitteln. Berlin, Heft II, 1899, 23.

[2] Die wicht. vegetab. Nahr.- u. Genussm. Berlin and Wien 1899, 17.

The histological elements include the distorted starch grains (Fig. 31), more or less bran tissues, and if yeast was used as the leavening agent, cells of the yeast plant.

Of the methods of examination described under flour, the diastase method, the hydrochloric-acid method, and the crude fiber process, are

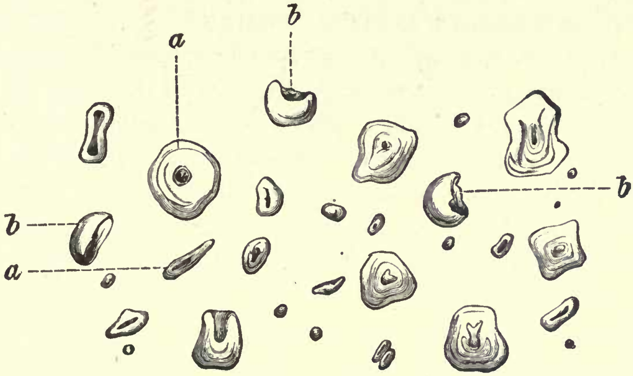

FIG. 31. Starch Grains from Wheat Bread. *a* typical forms, little altered; *b* broken and swollen forms. (MOELLER.)

also suited for the examination of bread, provided the material is first dried and ground to a moderate degree of fineness.

Chemical examination includes determinations of the usual proximate constituents, tests for alum and other baking chemicals, and, in the case of highly colored products, tests for artificial color.

Cattle Foods.

Mill Products. The mill products of wheat, rye, barley, rice and buckwheat, are more commonly consumed by the human family, only the by-products being cheap enough for cattle foods. Among the most important mill products designed especially for cattle, are maize meal, ground oats, and provender (a mixture of maize meal and ground oats). Of lesser importance are meals made from the chaffy wheats, sorghum, millet, and other cereals. These products are much coarser than flour designed for human use, and are invariably prepared from the whole kernel without separation of the bran or adhering chaff.

Mill By-products include the offals of flour mills, breakfast-food factories and some other industries. Among the most important materials are screenings, bran, and middlings, from wheat, rye, barley, maize, buckwheat, and rice, also more or less analogous materials designated by special names, such as hominy feed, oat feed, etc. These products, with the exception of screenings, which is treated in a separate chapter (pp. 145, 163), are described under the different cereals.

All of these materials contain starch grains in their original form.

By-products from the Manufacture of Starch and Glucose. In Europe starch and glucose are made chiefly from wheat or potatoes, in the United States almost exclusively from maize.

In the American factories, whether starch or glucose is the final product, the germ is first separated from the remainder of the grain and subjected to pressure to remove the oil. The oil-cake is similar to the cake of true oil seeds in that it contains no starch, but a high percentage of proteid and a considerable amount of residual oil.

Starch is separated mechanically from the remainder of the grain in a wet way and is purified for cooking and laundry purposes, or is converted by acid into glucose.

The dried residues from the processes are known as gluten meal, gluten feed, starch feed, etc. (p. 96). As they are dried at a rather high temperature the starch grains are distorted or entirely disorganized.

Brewery and Distillery By-products include malt sprouts, brewery grains and distillery grains.

Malt sprouts are the worm-like radicles removed from sprouted barley. They are quite simple in structure, and contain no starch in any form (p. 86).

Malt and distilled liquors may be made from any of the cereals. In Europe barley, rye and wheat are chiefly employed; in the United States, barley, rye and maize; in Japan, China, and India, rice and to some extent sorghum.

As the starch originally present in the grain is converted successively into sugar and alcohol, the residue or "grains" contain no appreciable amount of starch. Both wet and dry grains are used for feeding.

Chaff of oats, barley, rice, and weed seeds, also maize cob and buckwheat hulls, although of little value except for packing or fuel, are used for cattle foods, especially when mixed with more valuable material.

Oat and barley hulls are obtained in the factories where oatmeal and pearl barley are made and are ingredients of certain proprietary cattle foods containing, in addition to cereal constituents, some concentrated food, such as cottonseed meal or linseed meal.

Rice hulls, maize cob, peanut shells, and coffee hulls, notwithstanding their lack of valuable nutrients and their harsh woody structure, are not infrequently met with in cattle foods, especially as adulterants of bran.

Methods of Examination.

Preliminary Examination. The material should first be spread out on a paper and fragments of a suspicious nature picked out with forceps. This search is usually facilitated by separating the material by means of a series of sieves into several portions of different degrees of fineness. Many times impurities, such as chaff, insect remains, mouse excrement, etc., may be identified with the naked eye or under a lens, although more often positive identification is not possible without recourse to the microscope.

In bran the black hulls of cockle or of black bindweed are often present, the former being characterized by the rough outer surface, the latter by the smooth but dull surface and the regular shape of the larger fragments.

Foxtail (*Setaria*) is recognized by the mottled color and the transverse wrinkles on the flowering glumes and other weed seeds by the characters learned from the descriptions, as well as by comparison with standard specimens.

Rice hulls or chaff, even in quite small pieces, are recognized under a lens by their rough surface and straw-yellow color; oat hulls by the smooth convex surface; barley hulls by their smooth but ribbed surface; corn-cob by the hard fragments of the woody zone and the hard glumes, also by the papery thin glumes, often of a red color.

The bran coats of wheat and rye are rather soft, of a reddish or buff color; those of maize tough and horny, either white, yellow or red (rarely blue); those of oats and rice, thin and delicate, of a brownish-yellow color.

These are but a few of the macroscopic characters which either furnish positive evidence, or serve as a guide for microscopic examinations. The eye of the microscopist as well as his senses of taste, smell, and touch soon becomes trained to note very slight peculiarities, which often leads him to form an opinion before he has looked in his microscope.

The Chemical Analysis of fodders commonly includes the determination of water, ash, protein ($N \times 6\frac{1}{4}$), crude fiber, nitrogen-free extract (by difference) and fat. Determinations of starch, sugars, pentosans and albuminoid nitrogen are rarely desirable.

Microscopic Examination. As the cereal products and by-products used for cattle food are for the most part coarsely ground, and contain considerable amounts of the bran coats or chaff, their identification is usually easier than that of flour and other products consisting largely of starchy matter in the form of a fine powder.

Direct Examination. For the identification of starch grains an examination is made in water either of the fine powder separated from the coarse by sifting, or of a finely-ground sample of the whole material. Coarse fragments of a starchy nature picked out with the forceps are crushed, scraped or sectioned and likewise examined in water. Examination with the aid of polarizing apparatus is often useful.

Treatment with Reagents. Fragments of bran or chaff may also be examined directly in water, but much better results are secured after first dissolving the starch and other interfering substances, either by boiling for a moment in water on the slide (always under a cover-glass), or by mounting in dilute alkali or in chloral hydrate.

It is often convenient to examine the finely-ground material or isolated fragments, first in cold water, then after treatment with a small drop of iodine tincture, again after boiling, and still again after treatment with a small drop of 5 per cent potash or soda solution.

Crude-fiber Process. As most cattle foods contain a considerable amount of the bran coats and other tissues, there is commonly no need of resorting to the methods described under flour, as a means of accumulating the tissues from a rather large quantity of the material, although as a means of clearing the tissues, some of these methods, particularly Lauck's method, or what is practically the same thing, the crude-fiber process, are occasionally useful. After weighing the fiber a portion obtained in the quantitative determination of crude fiber may be used for microscopic examination, as the subsequent determination of ash in this fiber is not appreciably affected by the removal of the small quantity necessary for the purpose.

CEREALS (*Gramineæ*).

Most grasses are hermaphrodite, the organs essential to fertilization being in the same blossom, although in some blossoms either the male or female element is abortive. Maize is, however, monœcious, the flowers of the tassels being entirely male, those of the ear entirely female.

The inflorescence is in panicles, racemes, or spikes, made up of spikelets (Fig. 32, *A*), each consisting of two lower scales (*empty glumes*) on opposite sides of the axis, and one or more flowers (*B*), each usually inclosed by two scales, the one (*flowering glume*) situated on the outer side, the other (*palet*) two-veined and two-keeled, situated on the inner side with its back toward the axis. Sometimes the flower is inclosed by only one scale, in which case it is the palet that is lacking. Two minute hyaline scales (*lodicules*) are commonly present at the base of the flower and rarely a third occurs within the palet. The beard of the spikelets consists of coarse bristles, often barbed, which may be borne on the glumes or palets, in which case they are known as *awns* (e.g., wheat), or may spring from the base of the spikelet (e.g., Setaria). Commonly there are three stamens (rarely one, two, four, or six) with slender filaments and versatile anthers. The pistil has a one-celled ovary containing a single ovule, and one to three styles with feather-like stigmas. The flowering glume and palet, although free at the time

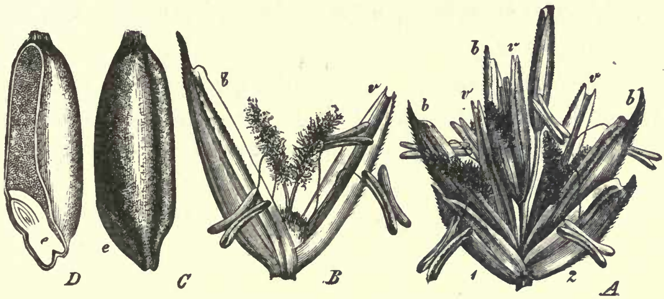

FIG. 32. Wheat (*Triticum sativum*). *A* spikelet with four flowers; *B* single flower; *C* whole fruit or caryopsis; *D* fruit in longitudinal section. 1 and 2 empty glumes; *b* flowering glumes; *v* palets; *e* embryo. (SCHUMANN.)

of flowering, sometimes become closely adherent to the fruit during ripening (e.g., barley), or so closely envelop it that they are not separated by threshing (e.g., oats).

In general appearance the cereal grains resemble seeds, but a study of their development clearly shows that they are true fruits. Each consists of a single fruit leaf with edges rolled over and grown together, the groove on the ventral side of wheat and other grains marking the line of juncture.

The fruit (Fig. 32, *D*; Fig. 62) consists of the bulky *endosperm* and the small *embryo* embedded in the endosperm at the base of the grain on the dorsal side, the whole being encased by the *pericarp* and *spermoderm*. The outer cell-layer of endosperm (in barley, two or more of the outer layers) contains proteid matters but no starch; the larger part of the endosperm, however, is a mass of large cells closely packed with starch grains. In the embryo three distinct parts are evident: the *plumule*, consisting of undeveloped leaves, the *radicle* or rootlet, and attached to these on the side adjoining the endosperm, the *scutellum* (cotyledon), which at the time of sprouting draws the nutritive matter from the endosperm and conveys it to the young plantlet. The embryo contains fat and proteid but no starch.

Microscopic Characters of the Cereals.

The Glumes and Palets have much the same structure as the leaves of which they are but modifications, and normally contain four distinct tissues:

1. *The Outer Epidermis* is made up largely of cells with wavy outline, arranged end to end in rows. Usually these wavy cells are strongly elongated, and between them are interposed isodiametric cells often extended beyond the surface as hairs ("silica cells") and twin cells, one of the twins being usually crescent-shaped.

2. *The Hypoderm* consists of one or more layers of sclerenchyma elements resembling bast fibers. This layer is imperfectly developed or entirely absent in the thin glumes and palets.

3. *Spongy Parenchyma*, corresponding to the mesophyl of leaves, makes up the third layer of variable thickness. In oats these cells are star-shaped, but in the other cereals they are more or less rectangular in form.

4. *The Inner Epidermis* is usually of thin-walled cells with less striking characters than the outer epidermis. Hairs are often present.

The Pericarp differs greatly in the number of layers and the form of the cells, but in general consists of four distinct tissues:

1. *The Epicarp* of porous cells, with or without hairs at the apex of the grain.

2. *The Hypoderm and Mesocarp*, often of porous cells.

3. *The Cross Cells* (so named by Wigand), a layer of cells transversely extended.

4. *The Tube Cells* (so named by Vogl) or endocarp, consisting of detached vermiform cells longitudinally arranged.

The Spermoderm of thin-walled cells is usually inconspicuous.

The Perisperm, or nucellar layer, also known as the hyaline layer, usually forms a thin coat of one or two layers of colorless, more or less obliterated cells, which, with suitable preparation and under favorable conditions, may be seen in surface view. In the case of sorghum, the layer is conspicuous and of diagnostic value.

The Endosperm. 1. The so-called "*Aleurone Cells,*" or "gluten cells" —both misnomers, as they contain neither aleurone grains nor gluten— form several layers in barley, but only one layer in other cereals. These cells have thick walls, and contain proteid matter and fat but no starch.[1]

2. *The Starch Parenchyma*, which makes up the great bulk of the fruit, is closely packed with starch grains varying greatly in shape and size according to the species.

Embryo. The cells are small and, like the aleurone cells, contain much oil and proteid matter but no starch.

Analytical Keys to the Cereals and Graminaceous Weed Seeds.

I. Key Based on the Structure of the Thick Glumes and Palets.

A. Outer epidermis of cells with wavy side walls, interspersed with circular cells (often forming hairs) and twin cells.
 (*a*) Spongy parenchyma of star-shaped cells.
  1. Circular cells forming conical hairs; saw-edge of hairs on keel of palet. . . Oats.
 (*b*) Spongy parenchyma of rectangular cells.
  2. Circular cells and saw-edge of hairs as in oats. Spelt, Emmer, One-grained Wheat.
  3. Circular cells as in oats; no saw-edge of hairs on palet. . . . . Barley.
  4. Circular cells represented by hair scars . . . . Sorghum.
  5. Circular cells large and porous; wavy cells often very short . . . . Darnel.
  6. Circular cells porous with wavy side walls; wavy cells long. . . . . Chess.
B. Outer epidermis of porous and non-porous cells, with thick, but not wavy walls, interspersed with hairs.
  7. Cells on the papery ends with thin wavy walls. . . . . Maize.
C. Outer epidermis mostly of one kind of cell with thick deeply sinuous side walls.
 (*a*) Epidermal cells broader than long, colorless.
  8. Surface rough; spongy parenchyma of rectangular cells. . . . . Rice.
 (*b*) Epidermal cells somewhat longer than broad, colorless, or mottled.
  9. Surface smooth, colorless. . . . . Common Millet.
  10. Surface with narrow wrinkles, colorless. . . . . German Millet.
  11. Surface with narrow wrinkles, mottled. . . . . Green Foxtail.
  12. Surface with broader wrinkles, mottled. Yellow Foxtail.

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[1] The early microscopists, believing that the outer starch-free layer of the endosperm was the seat of the gluten of the grain, gave to these cells the name gluten cells. Schenk, however, in 1872 showed that gluten, like starch, was present only in the inner endosperm cells, and Johannsen in 1883 reached the conclusion that the contents of the so-called gluten cells were aleurone grains embedded in fat. During the past twenty years the name aleurone cell has been slowly taking the place of the earlier name. v. Höhnel, Berthold, and other authors have not only accepted this view, but have used the size of the so-called aleurone grains as a means of distinguishing the different cereals, a procedure which has been severely criticized by Wittmack, Moeller, and others.

Recently Brahm and Buchwald have found that the name aleurone cells is quite as erroneous as the earlier term, since what appear to be aleurone grains embedded in fat are really fat globules in a ground substance of amorphous proteid matter. They state that a more exact name would be "protein cells", or, better still, "starch-free peripheral cells" of the endosperm.

II. Key Based on the Structure of the Bran Tissues.

A. Cross cells elongated polygonal, side by side in rows, forming a continuous layer.
- (*a*) Side walls of cross cells thick, distinctly beaded.
  1. Hairs less than 1 mm. long with narrow lumen.......................Wheat.
  2. Hairs often over 1 mm. long...................................Spelt.
- (*b*) Side walls of cross cells indistinctly beaded.
  3. End walls often swollen; hairs with broad lumen...................Rye.
  4. End walls of cross cells thin (not swollen)......................Emmer.
  5. Cross cells as in rye, hairs as in wheat................One-grained Wheat.
- (*c*) Walls of cross cells thin, not beaded.
  6. Cross cells in two layers......................................Barley.
  7. Hairs long, narrow at base.....................................Oats.
  8. Fungus layer usually present...................................Darnel.

B. Cross cells vermiform, forming an interrupted layer.
  9. Epicarp cells transversely elongated; walls non-porous; end walls deeply sinuous...Rice.
  10. Epicarp and hypoderm with wavy beaded side walls.............Sorghum.
  11. Epicarp with wavy side walls, not beaded..... { Common Millet, German Millet, Green Foxtail, Yellow Foxtail.[1]

C. Cross cells forming spongy parenchyma.
  12. Cells with long narrow arms; epicarp and mesocarp of s rongly developed, elongated, beaded cells; endosperm thin-walled.................Maize.
  13. Cells star-shaped or irregular; epicarp not beaded; mesocarp undeveloped; endosperm thick-walled.. ....Chess.

III. Key Based on the Characters of the Starch Grains.

A. Large starch grains mostly over 20 μ, round with indistinct hilum; feeble crosses, with polarized light.
  1. Many grains over 50 μ..Rye.
  2. Few grains over 50 μ...........Wheat, Spelt, Emmer, One-grained Wheat.
  3. No grains over 50 μ...Barley.

B. Large starch grains mostly over 15 μ, polygonal or round, with distinct hilum.
  4. Distinct crosses with polarized light....................Maize, Sorghum.

C. Grains less than 20 μ mostly polygonal, often in round or ellipsoidal aggregates.
  5. Occasionally spindle-shaped grains.................................Oats.
  6. No spindle-shaped grains...................................Rice, Darnel.

D. Grains less than 20 μ, mostly polygonal, never in rounded aggregates.
  7. Beaded network on treatment with alkali.... { Common Millet, German Millet, Green Foxtail, Yellow Foxtail.[1]

E. Grains less than 20 μ, ellipsoidal.
  8. Hilum elongated, very distinct...................................Chess.

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[1] Distinction by tissues of chaff.

WHEAT.

Common wheat (*Triticum sativum* var. *vulgare* (Vill.) Hackel), the most important of the bread cereals, is grown throughout the temperate regions of the earth. The numerous cultivated varieties differ greatly in habit of growth, hardiness, presence or absence of beards, and also in the form, size, and color, of the grain, but they are commonly grouped in two classes: the "Winter Wheats," or those sown in the fall and therefore adapted only to the warmer regions, and the "Spring or Summer Wheats," including the varieties grown in colder countries.

The grain of all these cultivated varieties readily separates from the chaff on threshing, and is termed "naked wheat" in contradistinction to the spelts, which, like barley and oats, are closely invested by the chaff.

Other species and varieties of wheat yielding naked grains are Polish wheat (*T. Polonicum* L.), English wheat (*T. sativum* var. *turgidum* (L.) Hackel), macaroni, hard or glass wheat (*T. sativum* var. *durum* (Desf.) Hackel), and hedgehog, or dwarf wheat (*T. sativum* var. *compactum* (Host.) Hackel).

The grain of common wheat (Fig. 32, *C* and *D*) is oval in longitudinal section, heart-shaped in transverse section. Other characteristics are the slightly-keeled back with a pronounced depression at the base marking the position of the embryo, the deep, longitudinal groove on the ventral side, and finally the beard on the end. In color the kernels vary from light yellow to brown. Rye kernels are longer, more slender, more pointed at the base, and of a darker color.

The kernels of macaroni and English wheat resemble those of common wheat in shape, but are larger.

Polish wheat is distinguished from all the other wheats by its long (often 12 mm.), slender, rye-shaped kernels with a sharp-pointed base.

HISTOLOGY.

As the glumes and palets of all the varieties named remain with the straw on threshing, they do not enter into the composition of mill products, and their anatomy is for us of no moment. All the naked wheats have practically the same structure.

After soaking the grain for some hours in water cross-sections may be cut with a razor or microtome, and surface preparations obtained by scraping.

Pericarp (Fig. 33, *F*). 1. *The Epicarp* (Fig. 33, *ep*; Fig. 34) is composed of colorless cells, which, except at the apex of the grain,

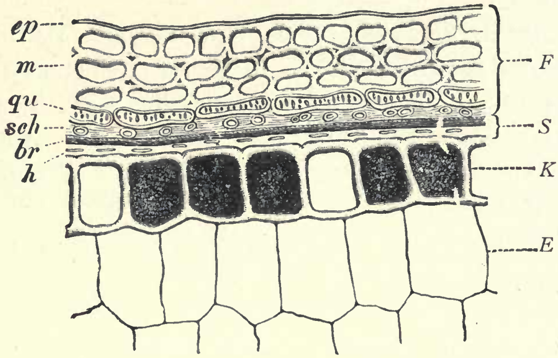


FIG. 33. Wheat. Cross section through bran coats and outer endosperm of fruit. *F* pericarp consists of *ep* epicarp, *m* mesocarp, *qu* cross cells and *sch* tube cells; *S* consists of *br* spermoderm and *h* perisperm; endosperm consists of *K* aleurone cells and *E* starch cells. ×160. (MOELLER.)

are longitudinally elongated and are arranged end to end (but not side by side) in rows. A thin cuticle covers the outer wall. On treat-

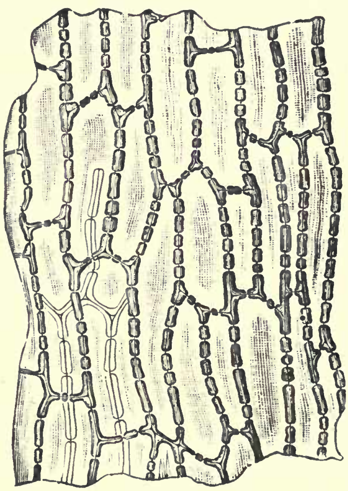


FIG. 34. Wheat. Epicarp in surface view. ×300. (MOELLER.)

FIG. 35. Wheat. Hairs from the apex of the grain. ×300. (MOELLER.)

ment with potash, the walls swell and turn yellow. Seen in surface view, both the side and end walls appear distinctly beaded, the double side walls being about 4 μ thick. At the apex the cells are more nearly isodiametric, and between them arise numerous hairs (Fig. 35) which vary up to 1 mm. in length and (measured near the base) up to 25 μ in diameter. Most of them are awl-shaped, with a more or less globular base, and, as Wittmack first noted, a narrow lumen or cell-cavity, the breadth of which is less than the thickness of the walls.

2. *The Mesocarp* (Fig. 33, *m*), consists of two or three layers of cells, which differ little from those of the epicarp.

3. *Cross Cells* (Figs. 33 and 36, *qu*). Beneath the mesocarp is another layer of cells with porous radial walls, but these are transversely elongated and, as may be seen in surface view, are arranged not end to end but side by side in rows. Over the larger part of the surface, the cells

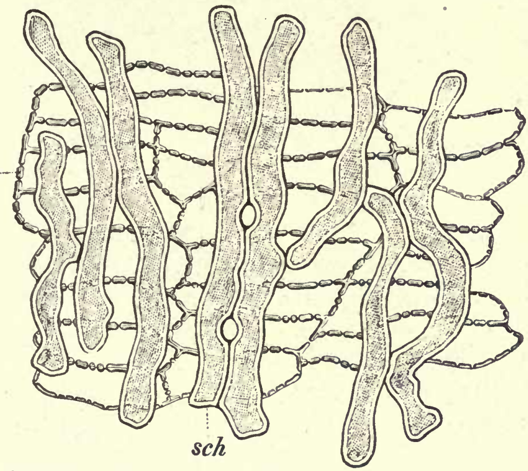


FIG. 36. Wheat. Surface view of *qu* cross cells and *sch* tube cells. ×300. (MOELLER.)

are 100–200 μ long and 15–25 μ broad, but in the region of the apex they are shorter and more irregular in form. The very distinctly porous, double side walls are about 7 μ thick, but the end and outer walls are often much thinner, and the end walls are never swollen as in rye. Intercellular spaces occur rarely. Treatment with alkali imparts a yellow color, but does not appreciably swell any of the walls.

This layer, from the diagnostic standpoint, is the most important of the bran tissues.

4. *Tube Cells* (Figs. 33 and 36, *sch*). Instead of an unbroken layer of cells, the endocarp of wheat, as of most of the cereals, consists of more or less detached vermiform cells arranged parallel to the axis of the grain. Oftentimes two adjoining cells are in interrupted contact, with circular intercellular spaces formed by sharp bends in the walls, suggest-

ing that this layer is but disintegrated spongy parenchyma. Cross-sections of these cells are circular or elliptical.

Spermoderm (Figs. 33 and 37, *br*). In cross-section, before treatment with reagents, the two layers of the spermoderm appear like yellow-brown, structureless membranes, the inner somewhat darker than the outer; but on treatment with Javelle water, the cell structure can often be recognized. Owing to their brown color, the layers are readily found in surface preparations. The thin-walled, elongated, pointed cells of the two layers cross one another.

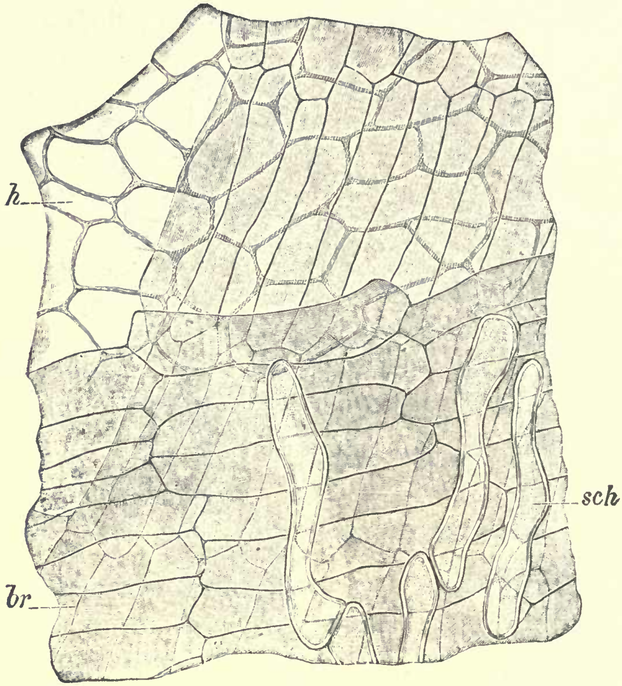


FIG. 37. Wheat. Surface view of *sch* tube cells, *br* two crossing layers of the spermoderm, and *h* perisperm. ×300. (MOELLER.)

Perisperm (Figs. 33, 37 and 38, *h*). The remains of the nucellus or body of the ovule, known as the "nucellar layer," and by some authors because of its colorless, almost structureless appearance, as the "hyaline layer," can be seen in surface preparations only under the most favorable conditions. To differentiate this layer, as well as others of the grain, Moeller proceeds as follows: Warm a whole kernel with alkali, wash in water containing a drop of acetic acid, remove to a slide a portion of the inner skin, which may be readily separated after this treatment, and gently press sidewise with a cover-glass. If zinc chloride iodine is now added, both cell layers of the spermoderm are colored brown, the perisperm and the remaining coats blue.

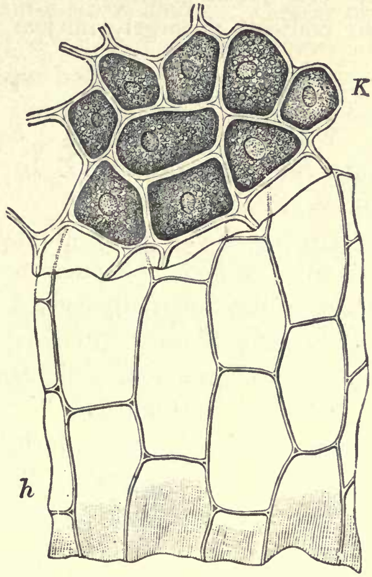


FIG. 38. Wheat. Surface view of *h* perisperm and *K* aleurone cells. ×300. (MOELLER.)

Endosperm. 1. *The Aleurone Layer* (Figs. 33 and 38, *K*) is but one cell layer thick. These cells, rectangular in transverse section, rounded polygonal in surface view, are 25–75 μ in diameter. Viewed in water, the double walls are about 7 μ thick; but on treatment with alkali, they swell considerably and also take on a yellow color. This layer contains proteids but no starch. Often the nucleus of the cell is clearly seen, especially in surface mounts.

2. *Starch Parenchyma* (Fig. 33, *E*). The large, isodiametric, thin-walled cells contain starch grains (Fig. 39) of two forms: (1) large, lenticular grains, mostly 28–40 μ (rarely 50 μ) with indistinct rings and hilum; (2) small rounded or polygonal grains, usually less than 8 μ. The large grains lying on edge are more or less elliptical in outline; with polarized light indistinct crosses dividing each grain into four equal parts are evident (Fig. 572, III). The small grains are detached members of aggregates, which are seldom found intact.

FIG. 39. Wheat Starch. ×300. (MOELLER.)

Embryo. Tissues of the embryo show little differentiation. The cells are small, seldom exceeding 25 μ. They contain fat and aleurone grains, but no starch. Treatment of sections with a mixture of iodine green or methyl green and fuchsin stains the cell nuclei green, the aleurone grains red. In many of the cells the contents is largely nuclear substance.

DIAGNOSIS.

Whole-wheat Products. *Roasted Whole Wheat* is used as a coffee substitute and adulterant. In over-roasted kernels it is often difficult to identify the tissues.

Graham Flour is the ground wheat kernel with nothing removed.

Rolled Wheat, a popular breakfast food, is the wheat kernel rolled and sometimes partially cooked, but not ground.

Shredded Wheat is prepared by shredding the kernel in machines of peculiar construction, and cooking.

"*Force,*" "*Malta-Vita,*" "*Zest,*" and numerous proprietary foods, consist chiefly of wheat which has not only been cooked, but also subjected to a malting process, thus converting a portion of the starch into maltose and dextrines. They come into the market either granulated or flaked.

These products contain all the histological elements of the wheat kernel; but in those which have been cooked, the starch grains are more or less distorted. The most characteristic tissues are the cross cells with distinctly beaded side walls and thin (never swollen) end walls, and the hairs 1 mm. or less long with lumen thinner than the walls.

Flour and Other Decorticated Wheat Products. *Wheat Flour* consists chiefly of the starchy portion of the grain with fragments of hairs which pass endwise through the bolts, and, less frequently, other tissues. The microscopist should note the size, form and deportment with polarized light, of the starch grains, also the characters of the tissues accumulated by one of the methods described on pp. 55–56.

In Europe rye flour is an occasional adulterant of wheat flour, and inferior wheat flour is a common adulterant of rye flour. Rye flour is characterized by the somewhat larger size of the starch grains and the presence of hairs with wide lumen. In America maize starch or flour is fraudulently added to wheat flour. Maize starch grains are identified by their size, polygonal form, and distinct crosses with polarized light.

Of great service in the identification of wheat flour, even in mixtures containing as little as 10 per cent, is the test which was devised in 1852 by Bamihl, a Prussian custom-house official. A small portion of the flour and enough water to form a rather thick paste are thoroughly mixed on a slide by rubbing with a cover-glass. Wheat flour yields by this treatment yellowish, stringy, glutinous masses in considerable amount, whereas maize flour yields only a very small amount, and rye flour none whatever. The test is of value in detecting wheat flour in buckwheat and rye flour.

Wheat flour, if made into a dough and kneaded in a stream of water to wash away the starch, finally yields an elastic mass of gluten; other kinds of flour are entirely washed away by this treatment and yield no gluten.

Weed seeds and other impurities of flour are discussed on pp. 49–52, and methods of examination on pp. 52–56.

Wheat Bread, Biscuit, and other bakers' products contain all the histological elements of flour, but the starch grains are more or less distorted (Fig. 31). In bread and other products raised with yeast, cells of the yeast plant are also present.

"*Grits,*" "*Cream of Wheat,*" etc., are coarsely ground kernels freed from bran, and differ from flour chiefly in mechanical condition.

By-products. *Wheat Bran* is an important cattle food, a common adulterant, and, after roasting, an ingredient of coffee substitutes. It consists largely of the pericarp, spermoderm, and gluten cells, with fragments of the germ, and considerable adhering starch. The cross cells, hairs, and starch grains should be carefully noted.

Among the accidental impurities of bran are the hulls and other elements of various weed seeds. The black hulls of cockle are distinguished from those of black bindweed by their rough surface as well as by the characteristic tissues. Other weed seeds of wheat are considered on pp. 145–148.

In bran adulterated with ground corn-cob, hard lumps of the woody zone, and hard glumes may be found under the dissecting lens, or by chewing the bran. These, as well as the white or red membraneous chaff, may be identified by the methods described on p. 96.

Corn Bran, a common adulterant, is identified by the thick pericarp. Broom-corn waste, coffee hulls, peanut shells, and some other adulterants may also be detected by their microscopic characters.

Wheat Middlings is a term used to describe various products intermediate between flour and bran, some being chiefly starch matter, others bran finely ground.

Wheat Germs, separated from the flour and bran in the flour mills, are used both as a human food ("Fould's Wheat Germ") and as a cattle food. They are much smaller in size than those of maize, the only other cereal from which the germs are removed on a commercial scale; but when finely ground cannot be readily distinguished from them.

Wheat Gluten, a by-product from the manufacture of starch, contains a preponderance of the nitrogenous materials (protein often 40 and sometimes 60 or more per cent). The starch grains are more or less distorted.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Berg (3); Blyth (5); Böhmer (6, 23); Hanausek, T. F. (16, 17); Harz (18); Hassall (18); Leach (25); Macé (26); Meyer, A. (27); Moeller (29, 32); Planchon et Collin (34); Schimper (37); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (43, 45); Wittmack (10).

BALLAND: Sur la falsification des farines avec le seigle, le sarrassin, le riz, l'orge, le maïs, les fères et la fécule de pomme de terre. Jour. pharm. chim. 1899, **9**, 239, 286.

BAMIHL: Pogg. Ann. 1852, 161.

BARNSTEIN: Roggen und Weizen. Landw. Vers.-Stat. 1902, **56**, 25.

BAUMANN: Nachweis von Maisstärke im Weizenmehl. Ztschr. Unters. Nahr.-Genussm. 1899, **2**, 27.

BENECKE: Zum Nachweise der Mahlprodukte des Roggens in den Mahlprodukten des Weizens. Landw. Vers.-Stat. 1889, **36**, 337.

BERTHOLD: Ueber den mikroskopischen Nachweis des Weizenmehles im Roggenmehle. Ztschr. f. landw. Gewerbe. Beilage, 1883.

BESSEY: The Structure of the Wheat Grain. Bull. Neb. Agr. Exp. Sta. 1894, **32**.

BRAHM und BUCHWALD: Botanische und chemische Untersuchungen an prähistorischen Getreidekörnern aus alten Gräberfunden. Ztschr. Unters. Nahr.-Genussm. 1904, **7**, 12.

COLLIN: Examen microscopique des farines de blé. Jour. pharm. chim. 1898, **8**, 97, 150, 200.

DANCKWORTT: Ueber Mehluntersuchungen (Bamihl'sche Probe). Arch. Pharm. 1871, **145**, 47.

HABERLANDT: Wissensch.-prakt. Untersuch. auf d. Geb. des Pflanzenbaues. **1**, 162.

HANAUSEK, T. F.: Zur mikroskopischen Unterscheidung des Weizen- und Roggenmehles. Ztschr. allg. österr. Apoth.-Ver. 1887, **25**, 143.

HANAUSEK, T. F.: Ueber die Untersuchung der Mehle. Oesterr. Chem.-Ztg. 1899, **2**, 103.

HANAUSEK, T. F.: Ueber die Griffigkeit der Mehle. Oesterr. Chem.-Ztg. 1900, **3**, 54.

v. HÖHNEL: Die Stärke und die Mahlprodukte. Kassel und Berlin, 1882.

JOHANNSEN: Studien über die Kleberzellen der Getreidearten. Bot. Centralbl. 1883, **15**, 305.

JUMELLE: Sur le constitution du fruit des Graminées. Comp. rend. 1888, **107**, 285.

KLEEBERG: Ueber einen einfachen Nachweis von Weizenmehl im Roggenmehl. Chem. Ztg. 1892, 1071.

KÖRNICKER und WERNER: Handbuch des Getreidebaues. Berlin, 1885.

KRAEMER: An Examination of Commercial Flour. Jour. Am. Chem. Soc. 1899, **21**, 650.

KRASSER: Mikroskopische Prüfung des Grieses. Ztschr. allg. österr. Apoth.-Ver. 1897, **35**, 543.

KRUTIZKY: On Some Peculiarities in the Structure of the Caryopsis of Wheat. Uebers. Leist. Gebiet. Bot., in Russland während 1891, St. Peters'g, 1893, 62; also in Just's Bot. Jahresb. 1893, **21**, I Abth. 571.

KUDELKA: Ueber die Entwicklung und den Bau der Frucht- und Samenhaut unserer Cerealien. Dissertation, Berlin, 1875.

LANGE: Die Mikroskopische Untersuchung von Mehl. Ztschr. angew. Mikrosk. 1896, 369.

LEBBIN: Arch. Hyg. **28**, 212.

LE ROY: Zum Nachweis von Sägespänen im Mehl. Chem. Ztg. 1898, 31; 1899, 264.

MAURIZIO: Kleberverteilung im Getreidekorn. Landw. Vers.-Stat. 1902, **57**, 405.

MAURIZIO: Getreide, Mehl und Brot. Berlin, 1903.

MOELLER: Die Mikroskopie der Cerealien. Pharm. Centralh. 1884, **25**, 507.

NEVINNY: Ueber Verunreinigung von Mehlen. Ztschr. Nahr.-Unters. Hyg. 1887, **1**, 205, 244.

SCHLICKUM: Morphologischer und anatomischer Vergleich der Kotyledonen und ersten Laubblätter der Keimpflanzen der Monokotylen. Dissertation, Marburg, 1895.

SPAETH: Nachweis des Mutterkorns im Mehl. Pharm. Centralh. N. F. 1896, **17**, 542.

STUTZER: Nahrungs- und Genussmittel. Handbuch d. Hyg. **3**, 243.

TARDIEN: Eichelmehl enthaltendes Weizenmehl. Ann. chim. analyt. 1898, **3**, 307.

VAUDIN: Sur un élément d'erreur dans la recherche du riz ajouté à la farine de froment. Jour. pharm. chim. 1899, **9**, 431.

VINASSA: Ueber mikroskopische Mehluntersuchung. Ztschr. Nahr.-Unters. Hyg. 1895, **9**, 53.

VOGL: Die gegenwärtig am häufigsten vorkommenden Verfälschungen und Verunreinigungen des Mehles, etc. Wien, 1880.

WAAGE: Zur Unterscheidung von Weizen- und Roggenmehl. Apoth.-Ztg. 1892, **7**, 430.

WEINWURM: Ueber die Verteilung der einzelnen Bestandteile des Roggen- und Weizenkornes auf die verschiedenen Mahlprodukte. Oesterr.-ungar. Ztschr. Zuckerind. 1890, **19**, 163.

WEINWURM: Ueber eine qualitative und quantitative Bestimmung von Weizenmehl im Roggenmehl. Ztschr. Unters. Nahr.- u. Genussm. 1898, **1**, 98.

WITTMACK: Sitzgsber. des bot. Ver. f. d. Prov. Brandenburg, 1882, 4.

WITTMACK: Anleitung zur Erkennung organischer und unorganischer Beimengungen im Roggen- und Wiezenmehle. Leipzig, 1884.

WOY: Vorbereitung von Mehlproben zur mikroskopischen Untersuchung. Ztschr. öffentl. Chem. 1900, **6**, 213.

Anon: Kartoffelfaser als Fälschungsmittel für Kleie. Pharm. Centralh. 1896, 181.

SPELT.

The three so-called "chaffy wheats," spelt, emmer, and one-grained wheat, differ from the common varieties in that the threshed grain, like oats, is closely invested by the chaff.

In ancient times spelt (*T. sativum Spelta* (L.) Hackel) was one of the leading cereals of Egypt, Greece, and Rome, but at the present time is of comparatively little importance. Its culture is limited chiefly to Southern Germany (particularly Wurtemberg), Switzerland, and Spain, and is slowly giving place to more valuable cereals.

Each of the more or less four-sided, loosely arranged spikelets consists of two truncate empty glumes clasping two to three flowers. The flowering glumes are thin, many-nerved, awned or awnless; the palets are still thinner, two-keeled. Some varieties have smooth, others hairy chaff. The grain is triangular with a dense beard. On threshing, the axis breaks at the joints and remains attached to the chaffy spikelets.

HISTOLOGY.

The Empty Glumes are thick, and of horny texture, except on the very edges, where they are membranous.

1. *Outer Epidermis.* As is true of most chaffy envelopes of cereals, the outer epidermis consists of elongated cells with wavy walls, "twin cells", one of which is more or less crescent-shaped, and circular cells, the latter often being extended beyond the surface in the form of hairs. Except on the edges, the cell-walls are thickened. Stomata occur in rows along the nerves.

2. *Hypoderm.* Several rows of thick-walled fibers are present except on the edges.

3. *Spongy Parenchyma* occasionally is present beneath the nerves, but does not form a continuous layer.

4. *The Inner Epidermis* is much like the outer epidermis, with thick wavy-walled, elongated cells, twin cells, circular cells, and stomata.

The Flowering Glume is thinner than the empty glumes.

1. *The Outer Epidermis* is practically the same as that of the empty glumes.

2. *The Hypoderm Fibers* are thin-walled and form only a thin layer.

3. *Spongy Parenchyma.* Rectangular spongy parenchyma cells form a continuous and well-developed layer in the central part of the glume, but are lacking on the edges.

4. *Inner Epidermis.* The cells are elongated polygonal and have very thin walls, which are usually straight, but near the nerves are often wavy. Awl-shaped hairs with swollen bases are numerous, especially toward the apex.

Palets. 1. *The Outer Epidermis* is practically the same as in the other envelopes. Thick-walled, tooth-like hairs, up to 200 μ in length, form a saw-edge on each of the two keels, much like those found on the palet keels of oats.

2. *Hypoderm Fibers* with thin walls occur throughout, except at the very edges.

3. *Spongy Parenchyma* is found only under the keels.

4. *Inner Epidermis.* Thin-walled, elongated polygonal cells, and short, awl-shaped hairs with globular bases form the inner layer.

Pericarp. The cells of the *Epicarp* and *Mesocarp* have thinner walls than those of wheat. Spelt hairs are considerably longer than wheat hairs, often reaching 1500 μ; the breadth of the lumen in some of them exceeds the thickness of the walls. The cross cells of wheat and spelt are very similar, though in the latter the walls are often not so thick nor so distinctly beaded. Tube cells occur in considerable numbers. The remaining layers are practically as described under wheat; the large starch grains, however, are somewhat smaller.

DIAGNOSIS.

The products of spelt are grits, other coarse human foods, and fodders.

Spelt chaff is distinguished from oat chaff by the rectangular cells of the spongy parenchyma. Rows of tooth-like hairs form a saw-edge on the palet keels of both spelt and oats but not of barley. Hairs 1000–1500 μ long, such as occur on the epicarp of spelt, are seldom or never found in wheat. The cross cells and starch cannot be distinguished with certainty from the same elements of wheat.

BIBLIOGRAPHY.

Hauptfleish: Die Spelzweizen. Landw. Vers.-Stat. 1903, 58, 65.

Netolitzky: Mikroskopische Untersuchung gänzlich verkohlter vorgeschichtlicher Nahrungsmittel aus Tirol. Ztschr. Unters. Nahr.-Genussm. 1900, **3**, 401.

Vogl: Die wichtigsten vegetabilischen Nahrungs- und Genussmittel. Berlin u. Wien, 1899, 75.

EMMER.

Two-grained, chaffy wheat, or emmer (*Triticum sativum* var. *dicoccum* (Schrank) Hackel), a cereal cultivated since prehistoric times, is now of little importance, its culture being limited chiefly to sections of South Germany, Switzerland, Spain, Servia, and Italy.

The flattened, often hairy spikelets are densely crowded in the spike.

Both of the empty glumes are strongly keeled and narrow gradually to the blunt-pointed apex, the keel being prolonged into a short tooth.

HISTOLOGY AND DIAGNOSIS.

The glumes and palets agree closely in structure with those of spelt, and the same is usually true of the pericarp, except as regards the cross cells. These latter are thin-walled and, as was rightly noted by Hauptfleisch, are even less distinctly beaded than the cross cells of rye. They are distinguished from the latter by the thin (not swollen) end walls. According to Hauptfleisch, the epicarp hairs of some varieties have broad lumens like rye hairs, but this distinction does not hold good for all varieties and cannot be depended on in diagnosis. The starch grains are slightly smaller than in common wheat.

BIBLIOGRAPHY.

See Spelt, p. 75

ONE-GRAINED WHEAT.

So distinct are the macroscopic characters of one-grained wheat from the preceding varieties that it is classed as a separated species (*T. monococcum* L.). Only one fertile flower is present in each spikelet, hence the German name Einkorn and the Latin and English names above given.

The empty glumes are rather thin, and have the nerve of the keel and the two side nerves continued as short teeth. Both the flowering glume and palet are membranous, the latter, on ripening, splitting longitudinally into two pieces.

HISTOLOGY AND DIAGNOSIS.

The glumes and palets have the same general structure as the corresponding parts of spelt, but the layers are not so robustly developed. Hauptfleisch has correctly observed that the awl-shaped hairs of the inner epidermis of the flowering glume are shorter than those of either spelt or emmer. In this layer the cell-walls, especially over the nerves, are often wavy. The epicarp hairs of one-grained and common wheat are not distinguishable, but the cross cells in the former are thin-walled and indistinctly beaded much as in emmer and rye.

BIBLIOGRAPHY.

See Spelt, p. 75.

RYE.

Rye (*Secale cereale* L.) is botanically closely related to wheat and ranks next to it in importance as a bread cereal.

The naked kernels are longer, more slender, sharper keeled, sharper pointed at the base and darker colored than those of wheat; they are also not so plump nor so uniform in form, size, and color.

HISTOLOGY.

The rye kernel is in general structure the same as the wheat kernel, but some of the layers show differences in detail which are of great importance in diagnosis. Treatment of sections with cold alkali or chloral hydrate swells the walls of the epicarp, middle layer, and perisperm, and aids in differentiating them.

Pericarp (Fig. 40). 1. *The Epicarp* is distinguished from the corresponding layer of wheat by the thinner and less distinctly beaded walls of the cells, and the thinner walls and broader lumens of the hairs (*h*). In both grains the epicarp cells are longitudinally elongated except at the apex, where they are more or less isodiametric. Often, but not always, the lumen breadth of rye hairs is greater than the wall thickness. Even at the apex of such hairs the lumen is distinct, whereas in wheat hairs it is reduced to a faint line.

2. *The Mesocarp* or *Middle Layer* is only one cell layer thick, and the walls are thinner than in wheat, and less distinctly beaded.

3. *Cross Cells* (*qu*). As in wheat, these cells cross those of the outer layers at right angles, and are further distinguished by the fact that they do not "break joints," but are arranged side by side in rows. They are 200 μ or less long and 15–35 μ wide. The side walls are thinner and less distinctly porous than in wheat; furthermore, the end walls are often rounded and swollen, with pronounced intercellular spaces, whereas in wheat they are thinner than the side walls and without spaces.

4. *The Tube Cells* are not numerous.

The Spermoderm and **Perisperm** of wheat and rye are hardly distinguishable.

Endosperm. 1. *The Aleurone Cells*, according to Vogl, are smaller and thicker-walled than in wheat. Moeller notes that on treatment with alkali the cell-walls swell greatly (Figs. 41 and 42).

2. *The Starch Parenchyma* contains starch grains (Fig. 43) of the

wheat type, but larger, a considerable number being over 50 μ. They often display delicate concentric rings, also fissures radiating from the

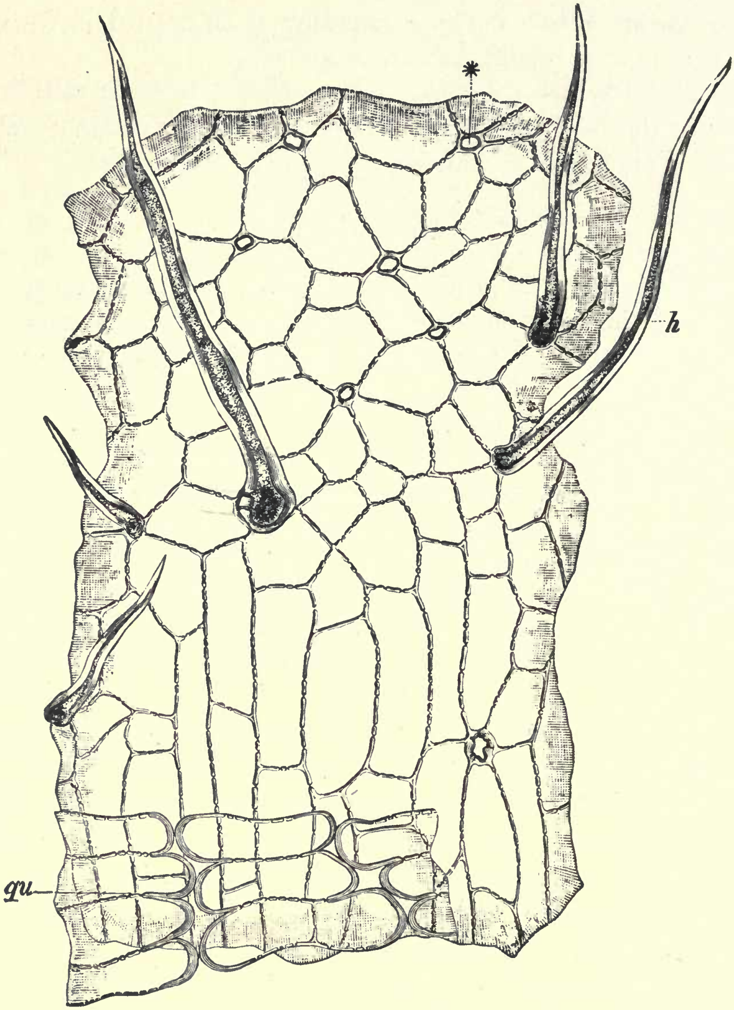


FIG. 40. Rye (*Secale cereale*). Outer bran layers in surface view. Epicarp consists of porous cells, *h* hairs and * hair scars; *qu* cross cells. $\times 300$. (MOELLER.)

hilum. The small grains are round or angular, seldom in aggregates.

DIAGNOSIS.

Whole Rye Products. *Roasted Whole Rye* is a coffee substitute and adulterant.

Rye Graham Flour. The ground whole kernel is used for coarse bread. Starch grains (Fig. 43), cross cells (Fig. 40, *qu*), and hairs (*h*) are the important elements.

Rye Flour prepared by the usual bolting process is not so white nor so fine as wheat and usually contains more bran elements. As it does

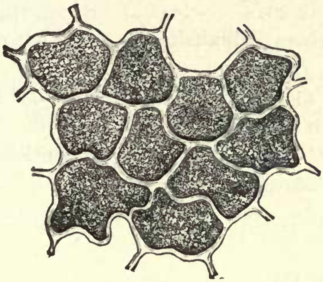


FIG. 41. Rye. Aleurone cells in water. ×300. (MOELLER.)

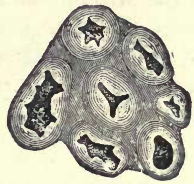


FIG. 42. Rye. Aleurone cells warmed in alkali. (MOELLER.)

not contain gluten it does not yield a glutinous, stringy mass by the Bamihl test, described on p. 70. Furthermore, the dough gradually washes away on repeated kneading under running water. The large starch grains (larger than in wheat) often with radiating fissures (Fig. 43),

FIG. 43. Rye Starch. ×300. (MOELLER.)

the hairs (Fig. 40, *h*) with lumen breadth often greater than the wall thickness, and occasional fragments of cross cells (*qu*) must be relied on in identification.

By-products. *Rye Bran and Rye Middlings*, well-known cattle foods, contain the coats of the grain and also more or less starch. The side walls of the epicarp, mesocarp, and especially the cross cells (Fig. 40, *qu*) are thinner and less distinctly beaded than in wheat. Some (but not all) the cross cells have swollen end walls.

BIBLIOGRAPHY.

See Bibliography of Wheat, p. 72–73.

EGGER: Ueber das Vorkommen blaugefärbten Zellinhaltes in der Kleberschicht von Roggenkörnern. Arch. Hyg. 1883, **1**, 143.

GREGORY: Die Membranverdickungen der sogenannten Querzellen in der Fruchtwand des Roggens. Beiträge z. wissensch. Bot. **2**, 165.

HANAUSEK, T. F.: Zur Mikroskopie des von der Presshefe abgepressten Roggenmehles. Ztschr. allg. österr. Apoth.-Ver. 1894, **32**, 416.

BARLEY.

Barley (*Hordeum sativum* L.), one of the most ancient of the cereals, is still cultivated in the northern countries of the Old World as a bread grain, and throughout the temperate zone for the production of malt.

The spikes consist of groups of three one-flowered spikelets arranged alternately on opposite sides of the zigzag rachis. In six-rowed barley (*H. sativum* var. *hexastichon* (L.) Hackel) and four-rowed barley (*H. sativum* var. *vulgare* (L.) Hackel) all of the flowers are fertile. In the former variety they form six equidistant, longitudinal rows, whereas in the latter only the middle flowers are arranged in distinct rows, alternating with two more or less indistinct rows formed by the side flowers. Only the middle flowers of two-rowed barley (*H. sativum* var. *distichon* (L.) Hackel) are perfect, the side flowers being staminate or neuter and much reduced in size. The grain of six-rowed and four-rowed barley and of many two-rowed varieties is so closely adherent to the flowering glume and palet that it is not freed from them by threshing, but the grain of some of the two-rowed barleys is naked or hulless.

Characteristic of the flowering glume are the five prominent ribs, the middle one being extended into a long awn, which, however, breaks off in threshing. The palet is grooved to correspond with the groove in the caryopsis, and is partially hidden from view by the overlapping glume. Both before and after the removal of the chaff, the grain is distinctly spindle-shaped. The groove on the ventral side of the caryopsis and the depression over the embryo at the base of the dorsal side are the same as in wheat and rye.

HISTOLOGY.

Cross-sections are prepared without removal of the glume and palet. Successive treatments of the section with potash, dilute acetic acid, and chlorzinc iodine solution, or Javelle water and safranin, aids greatly in differentiating the layers. The glume and palet are readily separated after boiling with water. The layers of these, as well as of the caryopsis, are obtained for study by scraping, and may be cleared and stained in the same manner as the cross sections.

The kernels of naked barleys are distinguished from the other varieties not only by the absence of chaff but also by their larger size and the thicker walls of the epicarp and middle layer.

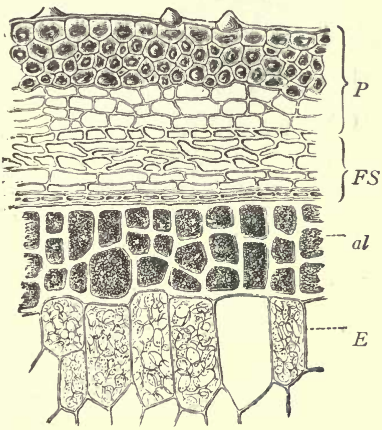


FIG. 44. Barley (*Hordeum sativum*). Cross section of palet and outer layers of fruit. *P* palet; *FS* pericarp and spermoderm; endosperm consists of *al* aleurone cells, and *E* starch cells. ×160. (MOELLER.)

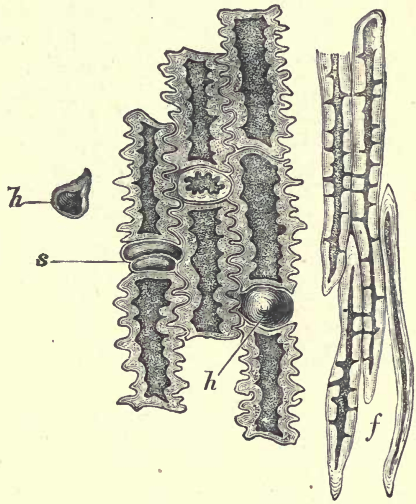


FIG. 45. Barley. Palet in surface view. Outer epidermis consists of elongated wavy cells, *h* circular cells extended into short hairs, and *s* twin cells; *f* hypoderm fibers. ×300. (MOELLER.)

The Flowering Glume and Palet (Figs. 44, *P*) are each made up of four layers.

1. *The Epidermal Cells* (Fig. 45) are strongly silicified and are of three forms. First, elongated cells with wavy side walls; second, small circular cells extended beyond the surface in the form of conical hairs (*h*); and third, crescent-shaped, hemi-elliptical or circular cells occur-

ring usually in pairs (*s*). Examined in water, the thickened, convoluted double walls of the long cells appear to be of uniform structure; but on treatment with alkali, the zigzag middle lamella separating adjoining cells is clearly evident.

2. *Hypoderm* (Fig. 44; Fig. 45, *f*). One to three layers of fibers with thick, porous walls, underlie the epidermis.

3. *Spongy Parenchyma* (Fig. 44; Fig. 46, *p*). This layer consists of thin-walled, rectangular cells, either isodiametric or slightly elongated with numerous circular, elliptical or irregular intercellular spaces.

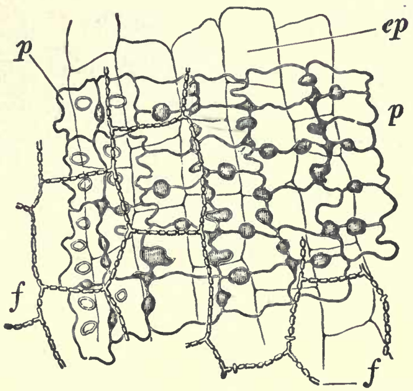


FIG. 46. Barley. Surface view of *p* spongy parenchyma of palet, *ep* inner epidermis of palet, and *f* epicarp. ×300. (MOELLER.)

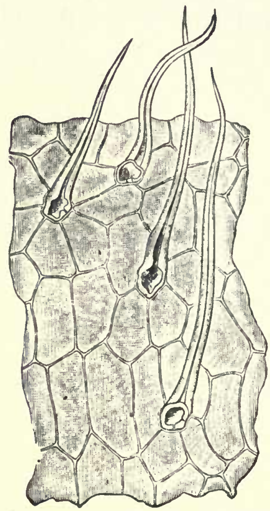


FIG. 47. Barley. Outer epidermis with hairs from margin of palet. (MOELLER.)

4. *Inner Epidermis* (Figs. 44 and 48). Cross sections show this layer indistinctly; surface preparations, however, bring out the thin-walled, elongated epidermal cells, stomata, and rather short, thin-walled, awl-shaped hairs, often with swollen bases.

Pericarp (Fig. 44). Little detail can be made out in cross sections mounted in water, but all the layers are evident on treatment successively with potash, dilute acetic acid and chlorzinc iodine.

1. *Epicarp* (Fig. 49). The cells have rather thin, porous walls. On the body of the grain they are longitudinally elongated; at the apex more nearly isodiametric. Vogl notes the occurrence of stomata. The numerous hairs which clothe the apex are less than 150 μ long. Some,

like wheat hairs, have walls thicker than the lumen, others, like rye hairs, have lumen thicker than the walls. Usually they are broadened at the base.

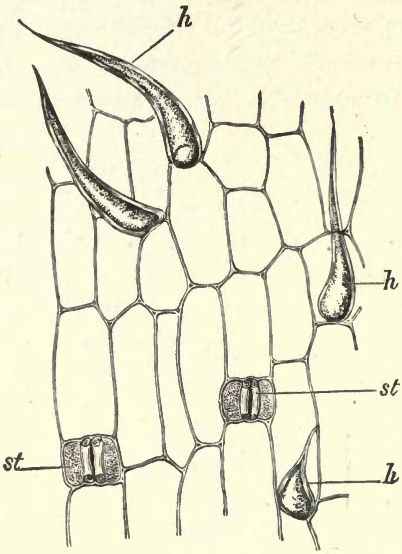


FIG. 48. Barley. Inner epidermis with *h* hairs and *st* stomata, from middle of palet. ×300. (MOELLER.)

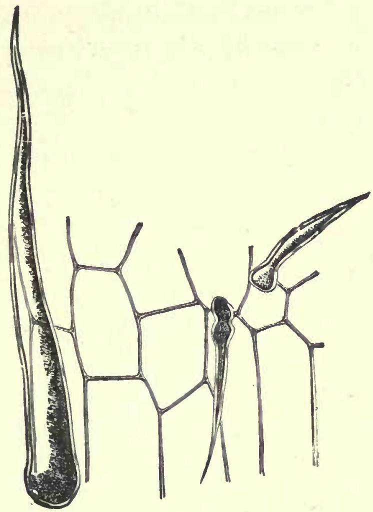


FIG. 49. Barley. Epicarp with hairs. (MOELLER.)

2. *Mesocarp.* Several rows of cells, similar to those of the epicarp, make up this layer.

3. *Cross Cells* (Fig. 50, *qu*). Two rows of cross cells with non-porous walls scarcely 2 μ thick, are found in barley. Most of the cells are 60–100 μ long and 10–25 μ wide, but in some parts they are nearly isodiametric. In both layers intercellular spaces frequently occur at the angles, and to some extent between the side walls.

4. *Tube Cells* (Fig. 50, *sch*) are not numerous.

The Spermoderm consists of two layers of elongated cells, but in both layers the cells are longitudinally extended, not crossed as in wheat and rye.

1. *The Outer Layer* (Fig. 50, *ie*) is composed of thin-walled cells, which can be clearly seen only after treatment with reagents. Chlorzinc iodine brings out the bright yellow cuticle.

2. *The Inner Layer* is composed of thick-walled cells. Treatment with potash greatly swells the walls, and subsequent addition of chlor-

zinc iodine colors the swollen walls blue and the cuticle on the inner wall bright yellow, but does not affect the middle lamella.

The Perisperm is often evident in section after soaking in dilute alkali, but is rarely seen in surface view.

Endosperm (Fig. 44). 1. *The Aleurone Layer* (*al*) differs from that of all other cereals in that it is two to four cell-rows thick. In cross section the cells are square or radially extended, but in surface view,

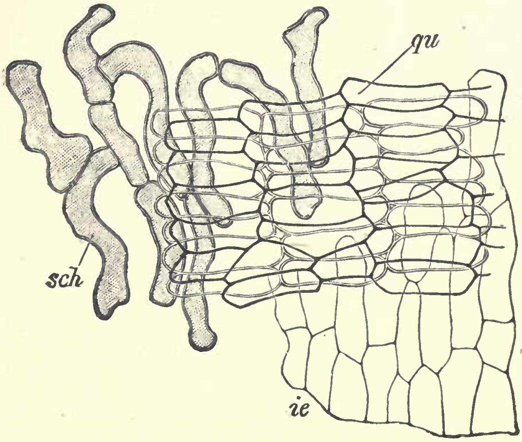


FIG. 50. Barley. Surface view of *qu* double layer of cross cells, *sch* tube-cells, and *ie* spermoderm. ×300. (MOELLER.)

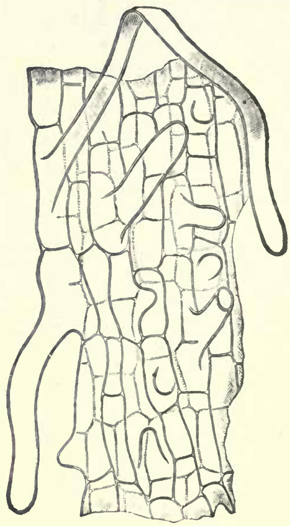


FIG. 51. Malt Sprouts. Epidermis with root hairs. (MOELLER.)

rounded polygonal, 18–30 μ in diameter, with double walls 4 μ or more thick.

2. *Starch Parenchyma* (*E*). Barley starch (Fig. 52) occurs in both large and small grains resembling closely those of wheat and rye, though smaller. The large, circular- or irregularly-shaped grains are commonly 20–30 μ in diameter and seldom exceed 35 μ. As aggregates are uncommon, the smaller grains are for the most part rounded and have few if any angles. Concentric rings and hilum are often evident.

DIAGNOSIS.

Whole Barley Products. *Malt*, the most important barley product, is prepared by first sprouting the grain, thus converting the starch into maltose through the action of the diastase ferment. As soon as this conversion is complete, the action of the diastase is stopped by heating, and the radicles, known as "malt sprouts," removed. Malt contains all the cellular elements of the grain but the radicles.

Roasted Barley and roasted malt are common coffee substitutes and adulterants.

Decorticated Products. *Barley Flour* is prepared for bread-making in some countries, and finer grades are used as food for infants and invalids.

Pearl Barley consists of the kernels denuded of the chaff and bran coats, and rounded. Tissues of the pericarp and spermoderm are found in the groove.

Barley Farina or grits is a decorticated product in a coarse granular form.

The characteristic elements of the decorticated products are the starch granules (Fig. 52), which are smaller than those of wheat or rye,

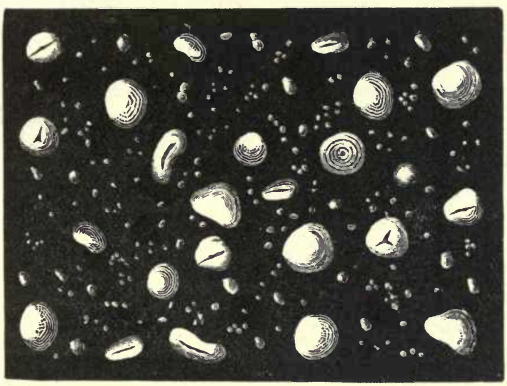


FIG. 52. Barley Starch. ×300. (MOELLER.)

the thick- and thin-walled hairs (Fig. 49), and occasional fragments of cross cells (Fig. 50, *qu*).

By-products. *Brewers' Grains* is the moist residue after extracting the sugars and other soluble materials from malt. Both wet and dry brewers' grains, also malt sprouts, are utilized as cattle foods. The glumes are distinguished macroscopically from oat glumes by the prominent ridges, and microscopically by the rectangular cells of the spongy parenchyma (Fig. 46, *p*). The thin-walled hairs of the inner epidermis (Fig. 48), the two layers of thin-walled cross cells (Fig. 50, *qu*), and the two or more layers of aleurone cells, further aid in diagnosis.

Malt Sprouts are the vermiform radicles removed in preparing malt. Dried sprouts are used as a food for cattle.

The central cylinder, consisting of incipient vascular elements, appears darker than the outer parenchyma zone. Numerous typical root hairs arise from the centers of epidermal cells (Fig. 51).

Other Cattle Foods containing chaff, bran, germs and starchy matter are obtained in the manufacture of pearl barley, barley grits, etc.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Berg (3); Böhmer (6, 23); Hanausek, T. F. (10, 16, 17); Harz (18); Hassall (19); Leach (25); Macé (26); Moeller (29, 32); Planchon et Collin (34); Schimper (37); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (43, 45); Wittmack (10).

Also see Bibliography of Wheat, pp. 72–73.

EMMERLING: Ueber eine einfache Unterscheidungsweise von Gersten- und Haferspelzen. Landw. Vers.-Stat. 1898, **50**, 1.

HOLZNER: Die Bestandteile und Gewebeformen des bespelzten Gerstenkornes. Ztschr. gesamm. Brauwesen. 1888, 473.

ZOEBL: Der anatomische Bau der Fruchtschale der Gerste (*Hordeum distichum* L.). Verhandl. Naturf. Ver. Brünn. 1889, **27**, 1.

ZOEBL: Beiträge zur Entwickelung des Gerstenkornes. Allg. Ztschr. f. Bierbrauerei u. Malzfabrikation. 1889.

MAIZE.

The fruit of maize or Indian corn (*Zea Mays* L.), a plant of American origin, is the leading cereal crop of the United States, the production being four times as great as that of wheat, and is also a valuable grain in Southern Europe.

By far the larger part of the grain is used as food for cattle, swine, and poultry, though a considerable amount is consumed by the human family in the form of corn-bread, mush, hominy, and various corn-starch products.

The varieties of maize cultivated in America are usually divided into five classes, viz.: dent corn (long kernels with a depression in the end), flint corn (kernels more nearly round, at the end smooth and convex), pop-corn (small kernels used for parching or "popping"), sweet corn (cooked green as a vegetable), and the less important soft corn. The numerous varieties belonging to each class vary greatly as to the number of rows of kernels on the cob, as to the size, form, and color of the kernels, the length and diameter of the cob, etc. Only the dent and flint varieties have any considerable importance as grain plants.

An ear of maize consists of a thickened rachis or spindle, on which are inserted the closely-packed kernels with their accompanying chaff. The spindle and chaff together form the cob.

The kernels of a maize ear spring from the cob transversely in pairs

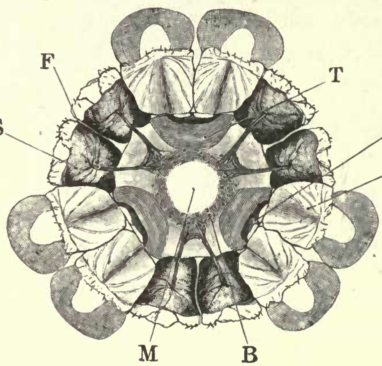


FIG. 53. Maize (*Zea Mays*). Cross section of ear looking toward the base. *S* inner surface of lower empty glume seen behind flowering glumes and palets; *s* outer surface of upper empty glume; *F* axis; *H* depression; *B* bundle zone; *M* pith. Natural size. (WINTON.)

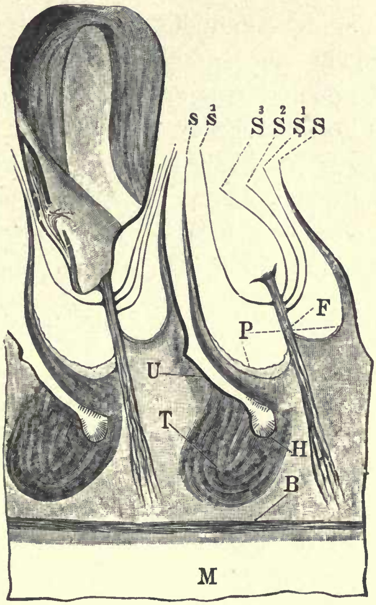


FIG. 54. Maize. Radial section of ear through the center of the kernels. *S* and *s* empty glumes; s^2 glume and S^3 palet of perfect flower; S^1 glume and S^2 palet of rudimentary flower; *P* spongy lining of thick glumes; *U* surface of woody zone beyond depression; *H* depression; *T* denser portion of woody zone; *B* fibro-vascular bundle; *M* pith. ×4. (WINTON.)

and longitudinally in double rows. The arrangement is such that a plane perpendicular to the axis of the cob which passes through the bases of the pair in one double row will pass alternately between and through the bases of the pairs in the other double rows. Since the double rows of kernels are arranged in pairs, it follows that there are normally an even number of rows. In the early stages of ripening, the double rows are separated by marked grooves; but as the kernels approach maturity they become so crowded that the arrangement in pairs and double rows may not be outwardly apparent, but is evident on cutting into the cob.

Fig. 53 shows a cross-section of an ear so cut as to leave three of the six pairs of kernels entire, alternating with three pairs of fruit cups in section; Fig. 54 shows a longitudinal section. The core of pith (*M*) is surrounded by a zone (*B*) containing numerous fibro-vascular bundles running longitudinally through the cob and this in turn by an outer woody zone bearing the fruit cups. The woody regions (*T*) beneath the double rows are separated from each other by thin radial partitions of soft tissues extending from the central pith nearly to the surface. These partitions can be traced the whole length of the cob separating the woody matter into strips which are arranged about the pith like the staves of a barrel. The strips of woody matter are pierced for the passage of the tissues connecting the kernels with the zone of vascular bundles.

On the surface of the woody zone between the pairs of fruit cups is a transverse depression (*H*) clothed with hairs, which is more or less pronounced according to the dryness of the cob. The woody matter (*T*) about these depressions is of a darker color than in other parts, owing to its greater density. The cups in which the kernels rest are formed by six envelopes, viz.: two empty glumes (*S* and *s*), the glume (s^2) and palet (S^3) of the perfect flower, and the glume (S^1) and palet (S^2) belonging originally to a rudimentary blossom. Both of the empty glumes are thick and horny with linings of spongy tissues (*P*) and thin ends resembling tissue paper. The other enveloping parts are entirely of this papery texture. Hairs occur at the bases of the thick glumes, especially at their points of juncture, and also on the thin ends. The more or less flattened kernels are usually longer than broad in the dent varieties, but broader than long in the flint varieties. The ventral side (the side nearest the apex of the cob) is smooth and flat, while the dorsal side has a broad groove extending from the base of the kernel (where it is broadest and deepest) nearly to the apex. Beneath this groove is the unusually large germ (Fig. 62).

HISTOLOGY.

Spindle. 1. *The Epidermis* overlying the woody zone in the depressions (Figs. 53 and 54, *H*) is made up of thin-walled cells of wavy outline arranged more or less distinctly in rows (Fig. 55, *ep*). The hairs

(*H*, *h*) which spring from this epidermis are, in part, long, pointed, single-celled, with walls from one-third to one-sixth the thickness of the cavity,

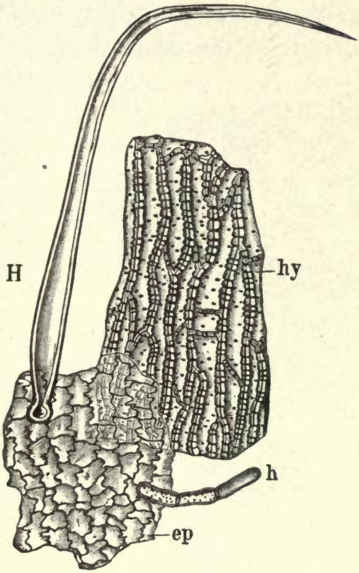
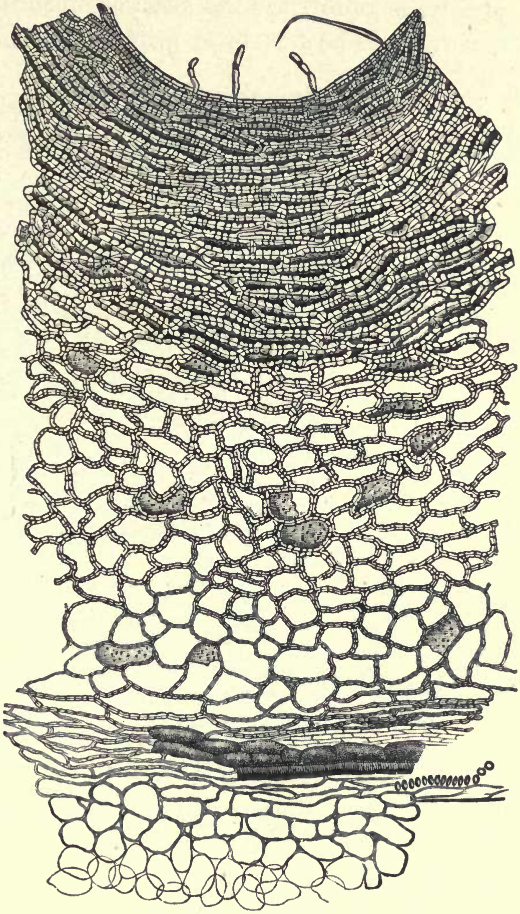


FIG. 55.



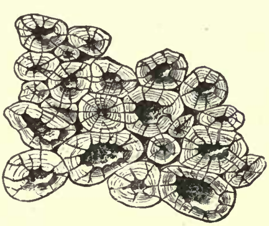


FIG. 57.

FIG. 56.

FIG. 55. Maize Cob. Surface view of *ep* epidermis and *hy* hypoderm in the depression (*H*, Figs. 53 and 54). *H* single-celled pointed hair; *h* blunt three-celled hair. ×160. (WINTON.)

FIG. 56. Maize Cob. Radial section through depression (*H*, Figs. 53 and 54), showing epidermis with hairs, elongated and isodiametric sclerenchyma cells, fibro-vascular bundle and parenchyma of pith. ×32. (WINTON.)

FIG. 57. Maize Cob. Transverse section through the elongated sclerenchyma of the woody zone. ×160. (WINTON.)

and, in part, blunt, two or more celled, with exceedingly thin walls.

In the region between the depressions and the base of the upper thick glume (Fig. 54, *U*), the epidermis is like that of the horny portion of the empty glumes (Fig. 59).

2. *Woody Zone.* The sclerenchyma cells of the woody zone vary greatly, according to their location, in form, size, and in the thickness of the walls. The first layer beneath the epidermis in the depressions, as

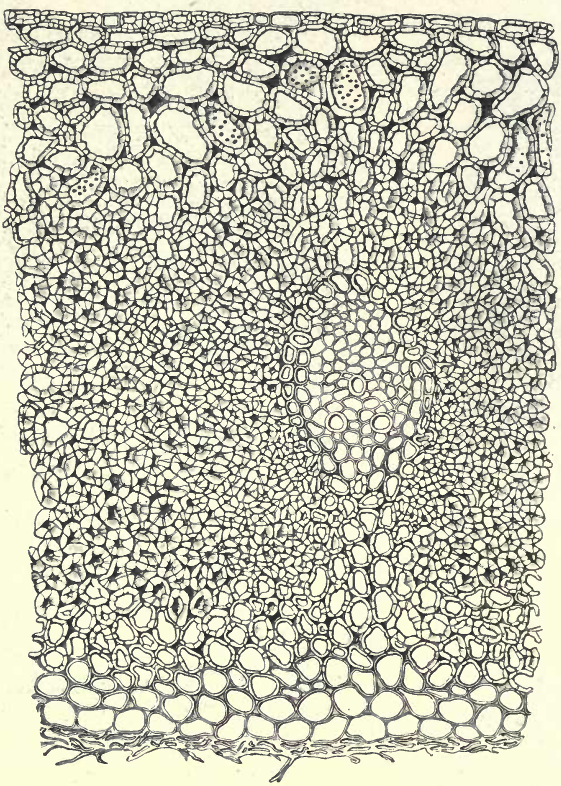


FIG. 58. Maize Cob. Cross section of upper thick glume. *ep* epidermis with thick-walled, porous cells and thin-walled non-porous cells; *st* isodiametric cells; *lf* longitudinally elongated sclerenchyma cells and fibro-vascular bundle; *p* parenchyma with compressed inner layers. ×160. (WINTON.)

seen in the surface view (Fig. 55, *hy*), consists of elongated cells with porous walls usually narrower than the lumen. The side walls are much thicker than those at the ends.

The cells of several succeeding layers are long and fibrous with narrow lumen, and extend in curves parallel to the surface of the depressions (Fig. 56).

Proceeding inward from these layers, the cells gradually diminish in length and increase in width until they are finally round or oval. At first this change in shape is accompanied by a thickening of the cell-wall; but further inward the walls begin to diminish in thickness and continue to diminish until the cells lose the character of sclerenchyma. All the transitional forms from woody fiber to the thin parenchyma of the pith are noticeable.

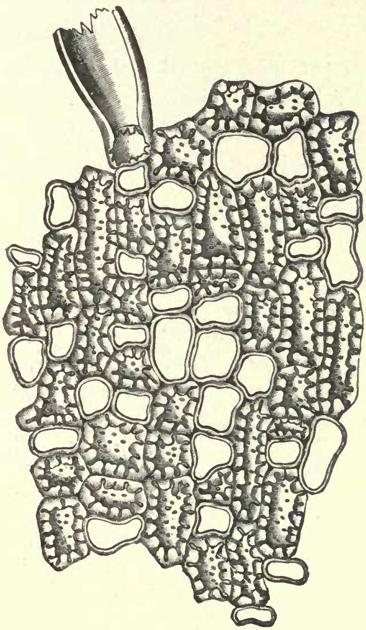


FIG. 59. Maize Cob. Outer epidermis of an empty glume, consisting of porous and non-porous cells and base of hair. × 300. (WINTON.)

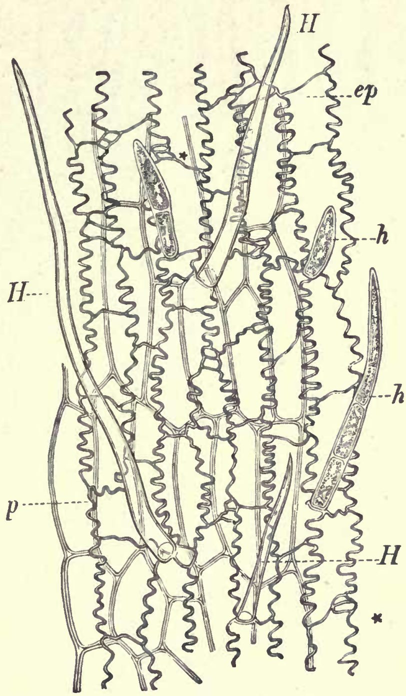


FIG. 60. Maize. Membranous glume in surface view. *ep* outer epidermis with *H* long one-celled hair, and *h* short, blunt 1–3 celled hairs; * hair scar; *p* inner epidermis. × 160. (MOELLER.)

In cross-sections of the cob the thick cell-walls show not only numerous pores, but beautiful concentric markings (Fig. 57).

3. *Bundle Zone.* The fibro-vascular bundles passing through the soft tissue between the woody zone and the pith have the characteristics peculiar to endogenous plants. In longitudinal sections, spiral, annular, scalariform, and pitted vessels and thin-walled elongated sclerenchyma cells are conspicuous (Fig. 56).

4. *The Pith* consists entirely of parenchyma with thin cell-walls which, under high power, are seen to be pierced by pores.

Empty Glumes. Each of the thick glumes (Fig. 54, *S*, *s*) is composed of a horny lower portion and a thin papery tissue at the end.

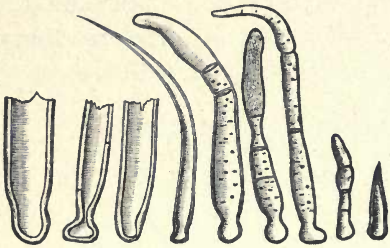


FIG. 61. Maize Cob. Hairs from different parts. ×160. (WINTON.)

The structure of the horny portion appears in cross section in Fig. 58. The epidermis (Fig. 59) is composed of two forms of cells, one with thick porous walls, the other with thinner walls free from pores. Both forms are commonly rounded-rectangular, either isodiametric or somewhat elongated. The non-porous cells are sometimes crescent-shaped, and often occur in pairs at more or less regular intervals, showing that they are analogous to the twin cells of other cereals. They are usually smaller than those with pores, although in some parts the difference in size is not so marked. In addition to these two forms of cells, hairs and well-developed stomata also occur in parts. The structure of the papery ends is like that of the thin glumes and palets.

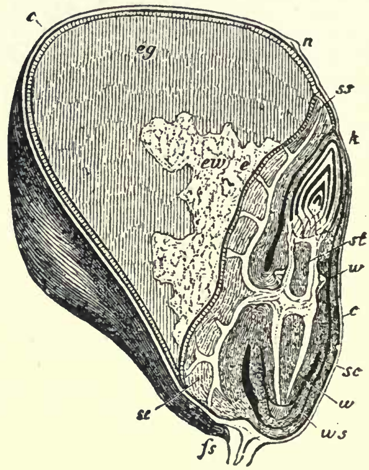


FIG. 62. Maize. Longitudinal section of fruit. *e* pericarp; *n* remains of stigma; *fs* base of kernel; *eg* horny endosperm; *ew* floury endosperm; *sc* and *ss* scutellum of embryo; *e* epithelium of scutellum; *k* plumule; *w* (below) primary root; *ws* root sheath; *w* (above) secondary root; *st* stem. ×6. (SACHS.)

2. *Sclerenchyma* (Fig. 58, *st* and *lf*). The sclerenchyma of the glumes extends from the epidermis nearly to the inner surface. In the first few layers, the cells are large, loosely arranged, more or less isodiametric, and have walls of moderate thickness; but further inward the cells are smaller, thicker walled and are longitudinally much elongated. The fibro-vascular bundles run among these elongated cells and parallel to them.

3. *Parenchyma* (*p*). Toward the inner surface the cell-walls diminish in thickness and the sclerenchyma passes finally into parenchyma. The parenchyma cells of the inner layers are indistinct and much compressed.

4. *The Inner Epidermis* is not evident.

Flowering Glumes and Palets (Fig. 60). 1. *The Outer Epidermis* (*ep*) consists of cells with thin wavy walls and thin-walled unicellular and multicellular hairs.

2. *The Inner Epidermis* (*p*) is of elongated cells.

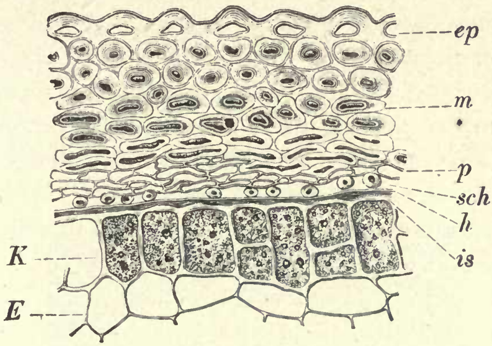


FIG. 63. Maize. Cross section of bran coats and outer endosperm of fruit. Pericarp consists of *ep* epicarp, *m* mesocarp, *p* spongy parenchyma and *sch* tube cells; *h* spermoderm; *is* perisperm; endosperm consists of *K* aleurone cells and *E* starch cells. ×160. (MOELLER.)

Pericarp (Figs. 63 and 64). After soaking the grain for a day or two in water, a skin, having the same color as the grain and consisting of the epicarp, mesocarp, and spongy parenchyma, may be readily sepa-

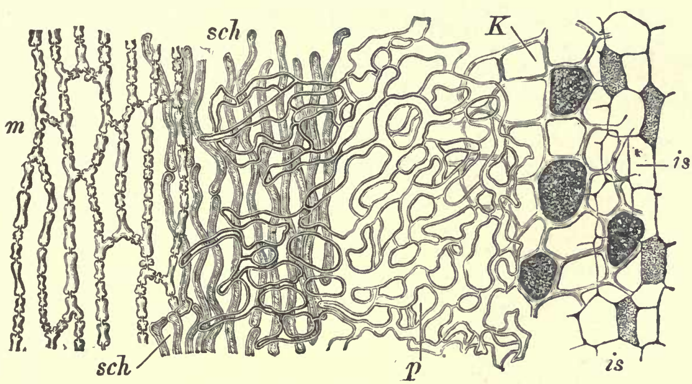


FIG. 64. Maize. Bran coats in surface view. *m* mesocarp; *sch* tube cells; *p* spongy parenchyma; *is* perisperm; *K* aleurone layer. ×160. (MOELLER.)

rated. If yellow or white, this skin turns deep yellow with alkali; if red, it turns green.

1. *The Epicarp* (*ep*) consists of porous-walled, elongated cells much like the corresponding layer of wheat, except that the walls are thicker. A thin cuticle covers the exposed surface.

2. *Mesocarp* (*m*). Six or more layers of cells similar to those of the epicarp, but with thicker walls, constitute the mesocarp, or middle layer. In the outer layers these cells are 600 μ or more long and 20–40 μ broad. In the inner layers, the cells are broader, flatter, and thinner walled, grading into those of the next layer.

3. *Spongy Parenchyma* (*p*). Instead of a close layer of cross cells, such as occur in wheat, rye and barley, or isolated vermiform cells, as in rice and sorghum, we find in maize a spongy parenchyma made up of branching and anastomosing cells with narrow, radiating arms, and large intercellular spaces. In most parts the transversely elongated arms occur in the greatest numbers, indicating the relation with the vermiform cross cells of rice and sorghum.

4. *Tube cells* (*sch*). In order to study the tube cells, also the spermoderm and perisperm, a whole kernel should first be soaked in water, stripped of the outer pericarp, as already described, and the thick inner skin removed. This skin should then be boiled in 1¼ per cent alkali, washed in dilute acetic acid, picked apart with needles, and the fragments mouuted in chlorzinc iodine.

Spermoderm (*is*). The so-called brown membrane, although exceedingly thin, is readily seen in cross-section. It becomes intensely yellow on treatment with alkalies, without swelling perceptibly. A single layer of delicate elongated cells and traces of a second are disclosed by the method described in the preceding paragraph.

Perisperm (*h*). Beneath the spermoderm is still another layer which, although seen in cross-section only under the most favorable circumstances, is brought out clearly in surface view by the method above described, the swollen walls remaining colorless, the finely granular contents, however, being stained deep blue.

Endosperm (Figs. 62, 63 and 64). 1. *The Aleurone Layer* (*K*) consists, for the most part, of a single cell layer, although some of the cells are divided by tangential partitions. The cells are 30–40 μ in diameter, the double walls 6–9 μ thick.

2. *Starch Parenchyma* (*E*). Immediately adjoining the aleurone layer, the cells are small and flattened; further inward, large and isodiametric. In the outer horny portion of the kernel, nearly all the starch grains (Fig. 65) are sharply polygonal, only a few being rounded; while in the inner mealy portion the reverse is true, nearly all the grains being rounded. A distinct hilum, often with radiating clefts, is always evident, at least in the larger grains. Most of the grains are 15–35 μ. Compound

forms do not occur. T. F. Hanausek has aptly described the starch grains of maize as standing out in bold relief, in striking contrast with the flat grains of many starches. Examined with crossed Nicols, maize starch displays very distinct crosses.

The Embryo (Fig. 62) contains oil and proteids, but no starch.

DIAGNOSIS.

The numerous products of maize serve not only as foods for man and beast, but also frequently as adulterants.

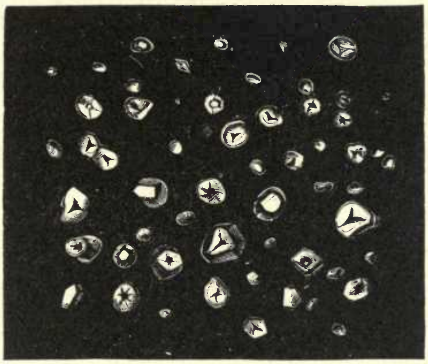


FIG. 65. Maize Starch. ×300. (MOELLER.)

Whole Maize Products. *Maize Meal.* Coarsely ground maize or coarse corn-meal is one of the principal forms in which this cereal is fed to cattle, swine, and horses.

Cracked Corn is a coarser product used as a poultry food.

From these products lumps of horny and floury endosperm and fragments of the bran and germ may be picked out under the simple microscope. The large polygonal starch grains (Fig. 65) differ from those of all other economic plants but sorghum. On treatment with alkali, yellow or white fragments of the skin become a deep golden-yellow and red fragments green. The pericarp is further characterized by the thick porous walls of the epicarp and mesocarp Fig. (64, *m*), and the star-shaped or transversely elongated cells of the spongy parenchyma (*p*). The tube cells (*sch*) are much like those of rice, oats, and sorghum.

Corn and *Cob Meal*, often known as "cob-meal," consists of the kernels ground with the cob. The characteristics of the cob are noted below.

Flour and Other Decorticated Products. *Maize Flour* is an ingredient of some griddle-cake flours and various other proparations. It is also an adulterant of wheat flour.

Maize Meal, more or less finely ground and freed from bran, is used for making corn bread ("Johnny cake") and mush ("hasty pudding").

Hominy, a coarser product made from white maize, is a well-known breakfast cereal. These and some other products consist largely of starchy matter.

"*Corn Crisp*" is one of several cooked and flaked preparations, with distorted starch grains.

Corn Starch (p. 651).

By-products. *Gluten Meal* and *Gluten Feed* are dried by-products from the manufacture of glucose. The former is a concentrated feed, consisting largely of hard, irregularly rounded, yellow lumps, the only marked microscopic elements being fragments of bran. Gluten feed contains more bran than does the meal. The starch grains are distorted in both products.

Hominy Feed and *Starch Feed,* by-products containing starchy matter and bran, are obtained in the manufacture of hominy and starch.

Maize Cake. The germs of maize yield, on pressing, maize oil. Ground germ cake is sold under the name "germ oil meal." It contains no starch.

Maize Bran, although much inferior to wheat bran, is frequently added to the latter as an adulterant, in which case it is detected by the cells of the epicarp, mesocarp, and spongy parenchyma (Fig. 64).

Maize Cobs, because of their mechanical condition and low content of nutrients, have little value as cattle food. Their legitimate use is as fuel and for making smoking-pipes; the ground cobs are, however, too often mixed with wheat or rye bran as an adulterant.

In bran, thus adulterated, a practiced eye, even without the aid of a lens, will usually find fragments of the thin glumes and palets, also of the thick horny glumes and woody zone. Lindsey notes that by chewing the bran the hard woody fragments may often be detected. The thin glumes and palets (Fig. 60) can be examined directly under the microscope, noting the color on addition of alkali; but pieces of the thick glumes and the woody zone require special preparation. The characteristic epidermal cells (Fig. 59) of the empty glumes are obtained for study by warming with dilute alkali and scraping with a scalpel. For the identification of other tissues, sections should be cut with a razor or the elements isolated by treatment with a macerating solution. Stone cells (Fig. 57), such as make up the woody zone of the cob and the interior of the thick glume, will be at once recognized as foreign to bran; and the same may be said of fibro-vascular bundles and the parenchyma of the pith. The compound hairs with thin walls, and sharp-pointed single-celled hairs with cavity five to six times the thickness of the walls, are readily distinguished from those of wheat or rye bran. Where the percentage of adulteration is large, chemical analysis will disclose a deficiency of nitrogen, fat, and starch and an excess of fiber, thus confirming the results of the microscopic eqamination.

Usually the thin glumes (Fig. 60) with sinuous walls and hairs, also the porous and non-porous epidermal cells (Fig. 59) of the thick glumes, suffice for identification.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674; Berg (3); Böhmer (6, 23); Hanausek, T. F. (16); Harz (18); Hassall (19); Leach (25); Macé (26); Moeller (29); Planchon et Collin (34); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (43, 45); Wittmack (10).

Also see Bibliography of Wheat, pp. 72–73.

BERSCH: Mais und Maisabfälle. Landw. Vers.-Stat. 1895, **46**, 85.

HARSHBERGER: Maize, a Botanical and Economic Study. Contrb. Bot. Lab. Univ. Pennsylvania I, 1893, 75.

LINZ: Beiträge zur Physiologie der Keimung von *Zea Mais* L. Dissert. Marburg, 1896.

PAMMEL: Comparative Anatomy of the Corn Caryopsis. Iowa Acad. Sci. 1897, **5**, 1.

WHITE: Note on the Use of Maize as an Adulterant. Analyst, 1895, **20**, 30.

WINTON: Die Anatomie des Maiskolbens mit besonderer Rücksicht auf den Nachweis von Kolbenmehl als Verfälschungsmittel der Weizen- und Roggenkleie. Oesterr. Chem.-Ztg. 1900, **3**, N. F., 345. Conn. Agr. Exp. Sta. Rep. 1900, 186.

BROOM CORN.

A number of plants formerly regarded as separate species of the genus Sorghum (*S. saccharatum* Pers., *S. vulgare* Pers., *S. Caffrorum* Beauv., *S. nigrum* Roem. et Schult., *S. cernuum* Willd.) are now classed as varieties of a single species (*Andropogon Sorghum* Brot.), the extraordinary differences in their inflorescence and fruit being the result of hybridization and selection extending through centuries. These differences are especially marked, because some of the varieties have been developed for grain, others for brush, and still others for sugar; whereas in the case of other cereals the production of grain has been chiefly considered.

Broom corn (*Andropogon Sorghum* var. *technicus* Koern.), one of the most important varieties, is grown in large quantities in Illinois, Kansas, Nebraska, and some other states of the United States, and to a much lesser extent in Spain, Italy, and other parts of Europe. Although the grain is not fully ripe when the brush is in its best condition, still it is utilized to some extent as food for cattle and poultry, and sometimes is mixed with wheat bran as an adulterant.

A fertile spikelet (Fig. 66) and one or two staminate or rudimentary spikelets (*r*) are borne at each joint of the panicle. The fertile spike-

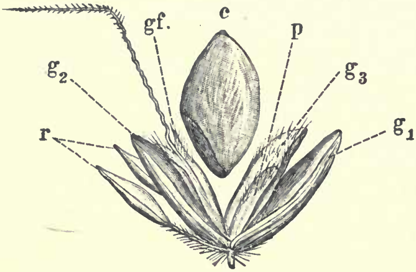


FIG. 66. Broom Corn (*Andropogon Sorghum* var. *technicus*). Fruit with chaff. *r* two staminate spikelets; g_1 lower empty glume; g_2 upper empty glume; g_3 glume of rudimentary flower; *gf* flowering glume with awn; *p* palet; *c* caryopsis or fruit. ×4. (WINTON.)

let consists of two shining, thick, empty glumes (g_1 and g_2) and three membranous, hairy envelopes, constituting the glume (*gf*) and small palet (*p*) of the perfect flower, and the glume (g_3) of a rudimentary flower. A geniculate upwardly barbed awn, 5–7 mm. long, is borne on the glume of the perfect flower; but this awn, being readily detached by threshing, is seldom found in the grain on the market. The grain or caryopsis is about 5 mm. long and from 2–3 mm. wide, tapering to a blunt point at both ends. It varies in color from yellow-brown to red-brown.

HISTOLOGY.

Both Empty Glumes (Fig. 66, g_1 and g_2) are from 4 to 6 mm. long, equalling and closely enveloping the fruit. They vary in color from yellow-brown to red-brown. The soft hairs, which nearly cover the outer surface, are loosely attached and most of them are removed during the threshing and cleaning of the seed, leaving the glumes smooth and shining.

1. *The Outer Epidermis* (Figs. 67 and 68, *aep*) consists of thick-walled sclerenchyma cells several times as long as broad, with wavy con-

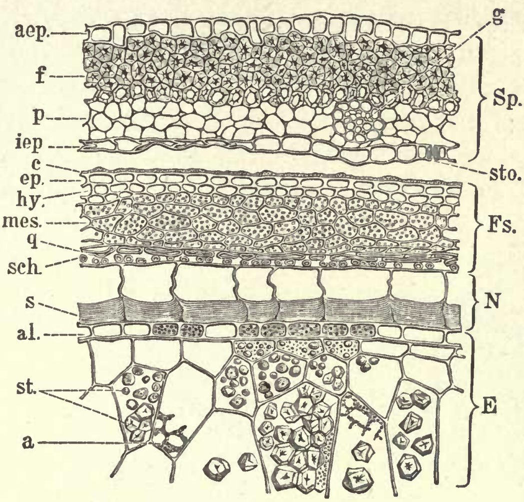


FIG. 67.

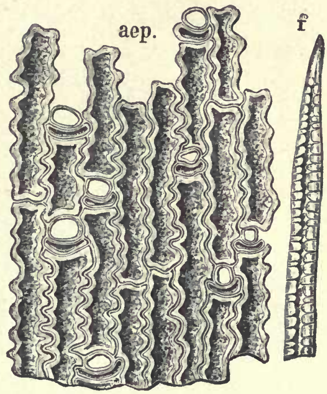


FIG. 68.

FIG. 67. Broom Corn. Transverse section of empty glume and outer layers of fruit. *Sp* empty glume consists of *aep* outer epidermis, *f* fiber layer, *p* spongy parenchyma with *g* bundle, and *iep* inner epidermis with *sto* stoma; *Fs* pericarp consists of *ep* epicarp with *c* cuticle, *hy* hypoderm, *mes* starchy mesocarp, *q* cross cells and *sch* tube cells; *N* perisperm with *s* swollen inner walls; *E* endosperm, consists of *al* aleurone layer and the starch cells with *st* starch grains and *a* proteid network. ×160. (WINTON.)

FIG. 68. Broom Corn. *aep* outer epidermis and *f* fiber of an empty glume in surface view. ×300. (WINTON.)

tour, interspersed here and there with isodiametric hair-scars, each accompanied by a crescent-shaped cell with granular contents. The hairs, which are almost invariably detached in preparing the mount, if not in cleaning the seed, are often 1.0 mm. long and 12 μ broad in the middle, but tapering towards both ends. Invariably the lumen is much broader than the walls.

2. *The Hypoderm Fibers* (Figs. 67 and 68, *f*), of which there are several layers, have thick walls and narrow cavities.

3. *Spongy Parenchyma* (Figs. 67 and 69, *p*). As seen in surface view, the cells of this layer are more or less rectangular with circular intercellular spaces, and resemble those of rice and barley glumes.

4. *Inner Epidermis* (Figs. 67 and 69, *iep*). In cross-section this layer is not readily studied, since the radial walls are usually collapsed; but in surface preparations, the large elongated cells, often 150 μ long and 50 μ wide, interspersed with stomata and hairs, are clearly displayed.

Flowering Glumes and Palet. 1. *Outer Epidermis* (Fig. 70, *aep*). In general form the cells are similar to those of the outer epidermis of the empty glumes, but are narrower and much thinner walled. The marginal hairs (*h*) are long (often 500 μ), single-celled, and pointed;

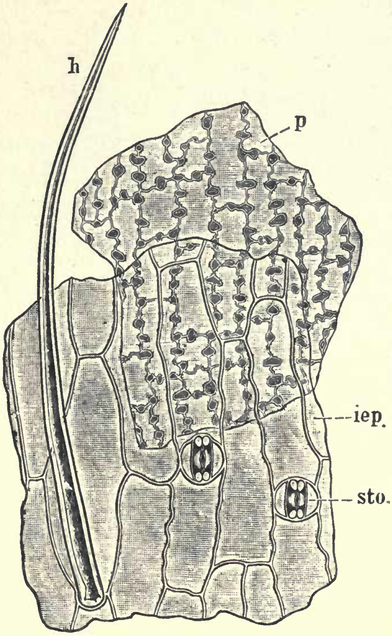


FIG. 69. Broom Corn. Inner layers of empty glume in surface view showing *p* spongy parenchyma and *iep* inner epidermis with *sto* stoma and *h* hair. ×300. (WINTON.)

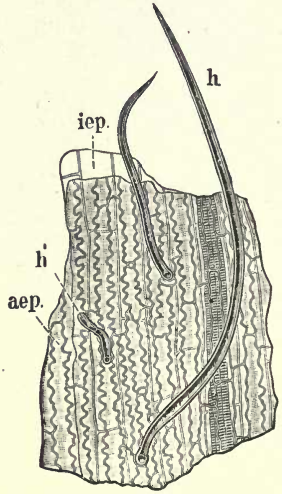


FIG. 70. Broom Corn. Glume of rudimentary flower (Fig. 66, g_3) in surface view. *aep* outer epidermis with *h* one-celled hair and h^1 two-celled hair; *iep* inner epidermis. ×300. (WINTON.)

but on the surface, shorter hairs (h^1), with two or three joints and blunt ends, also occur. Both of these forms have exceedingly thin walls.

2. *The Inner Epidermis* (*iep*) is distinguished from the outer by the straight walls, and almost entire absence of hairs.

Pericarp. 1. *Epicarp* (Figs. 67 and 71, *ep*). The cells are longitudinally extended and have thick, wavy side walls, with more or less distinct pores. Hassack has noted that the cuticle (*c*) is of uneven thickness, due to minute granules or crystals, which may be seen either in section or surface view.

2. *The Hypoderm* (*hy*) consists of from one to three layers of cells, with walls somewhat thinner than those of the epidermis.

3. *Starchy Mesocarp* (*mes*). Several layers of thin-walled parenchyma cells, filled usually with small round or rounded polygonal starch grains, seldom over 6 μ in diameter, make up this coat. The starch appears during the early stages of growth and persists until the fruit nearly or quite reaches full maturity. As the caryopsis, even when nearly mature, is intensely green owing to chlorophyl grains in the outermost layers of the mesocarp, it may be inferred that this starch is a direct product of assimilation in the pericarp. The presence or absence of a starchy mesocarp in the grain at the time of harvest is not a definite varietal pecu-

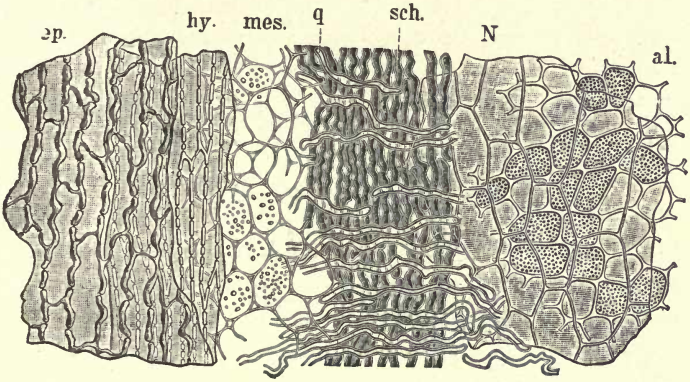


FIG. 71. Broom Corn. Bran layers in surface view. *ep* epicarp; *hy* hypoderm; *mes* starchy mesocarp; *q* cross cells; *sch* tube cells; *N* perisperm; *al* aleurone cells. $\times$ 160. (WINTON.)

liarity, but is dependent on the ripeness of the fruit or other conditions. Some kernels of the same variety may possess it, while others show only empty, obliterated cells. Whether or not the starch is present in a given seed may often be determined by careful scraping and observation with the naked eye.

4. *Cross Cells* (*q*). These cells are usually long and narrow, being distinguished from the tube cells only by their transverse arrangement. Near the extremities of the seed they are, however, shorter and of more irregular shape.

5. *Tube Cells* (*sch*). The cells of this layer lie at right angles to the cross cells. They are about 5 μ wide and often reach a length of 200 μ.

Perisperm (*N*). This layer is frequently 50 μ thick. The outer radial walls are thin, but the inner wall (*s*) is greatly swollen. In surface view the large cells are conspicuous, not only because of their size, but because of their yellow or brown color.

Endosperm. 1. *Aleurone Layer* (*al*). The individual cells of this layer are characterized by their great variation in size and form.

2. *Starch Parenchyma* (*st*). In the outer layers the starch grains, if present, are much smaller than in the interior of the seed, where they sometimes reach a diameter of 30 μ. They are usually sharply polygonal, with a distinct hilum and radiating fissures. The starch is surrounded by small protein granules, forming a network (*a*) which is especially evident after removing the starch by reagents. In some specimens, one or more of the outer cell layers are filled with these protein granules to the complete exclusion of the starch.

DIAGNOSIS.

The starch grains of broom corn and other sorghum fruits are practically the same, both in form and size, as those of maize, although radically different from those of all other cereals. Meyer observed that the grains of some varieties of sorghum take on a reddish color, not a blue, with iodine solution, but Mitlacher found that this reaction takes place only after first soaking the grain in water. As a means of distinguishing sorghum starch from maize starch, this test is of little value, and it is necessary to depend on the differences in structure of other histological elements

The epidermis (Fig. 68) of the glumes and the perisperm (Fig. 71, *N*) of both broom corn and sugar sorghum are radically unlike any tissues found in maize. Especially characteristic are the cells of the perisperm, which may be readily found without treatment with reagents, whereas in other cereals they can seldom be seen except under the most favorable conditions.

After treatment with alkali, the epidermis (Fig. 68, *aep*) of the empty glumes may be readily distinguished from the corresponding tissues of maize by the longer cells, their zigzag contour and the crescent-shaped cells which almost invariably accompany the hair-scars. The thin glumes (Fig. 70) resemble those of maize (Fig. 60), but the epidermal cells are longer, narrower and less irregular in form.

The tube cells of the two cereals are much the same, and the cross cells of sorghum are often not distinguishable from the spongy parenchyma cells of maize. Of the other tissues, the epicarp is not always characteristic, and the starchy mesocarp is difficult to find in the ground product.

The elongated cells of the outer epidermis of the thick glumes in sorghum and barley are much alike, but the short conical hairs, often unaccompanied by crescent-shaped cells, are characteristic of barley. Sorghum and oat glumes are not so readily distinguished by the epidermal tissues; but in sorghum the cells of the spongy parenchyma are, like those of barley, irregularly rectangular with round intercellular spaces, whereas in oats they are star-shaped.

BIBLIOGRAPHY.

See general Bibliography, pp. 671–674: Hassall (19).

BROWN: On Another New Pepper Adulterant. Analyst. 1887, **12**, 89.

HARZ: Landw. Samenkunde. Berlin, 1885, **2**, 1249.

HASSACK: Anatomie der Sorghum-Früchte. Mitth. aus dem Labor. f. Waarenk. an der Wiener Handels-Akad. 1887, 113.

MITLACHER: Ueber einige exotische Gramineenfrüchte, die zur menschlichen Nahrung dienen. Ztschr. allg. österr. Apoth.-Ver. 1901, 813, 831, 856, 875, 899 u. 928.

WINTON: Anatomie der Kultur-Varietäten der Hirse. Ztschr. Unters. Nahr.-Genussm. 1903, **6**, 337. Conn. Agr. Expt. Sta. Rep. 1902, 326.

SUGAR SORGHUM.

Sugar sorghum (*Andropogan Sorghum* var. *saccharatus* Koern.) has been cultivated for many years in China and Africa and for the past half century in America. At one time it gave promise of being the chief sugar plant of the United States, but has since largely given place to the sugar beet. It is cut for sugar before the seeds reach maturity, but the latter still have some value as food for stock. When grown to maturity the seed are said to be equal or superior to durrha.

Early Amber, Early Orange and other important varieties resemble closely the broom corns in habit of growth, but the panicles are shorter and less spreading. The two black, shining, empty glumes are of about the same length as those of broom corn, but are somewhat broader and, since they do not so closely envelop the caryopsis, are sometimes, though not usually, removed in threshing.

Numerous loosely attached hairs cover the surface of these empty glumes, but they, as well as the awned flowering glumes, drop off in the preparation of the grain for the market.

Under the microscope the two varieties named cannot be distinguished from the broom corns except by the material in the epidermal cells of the empty glumes, to which they owe their black color.

BIBLIOGRAPHY.

See Broom Corn, p. 103.

KAFFIR CORN.

Kaffir corn (*Andropogon Sorghum* (L.) Brot.) is the chief bread cereal and cattle food of the natives in parts of South Africa, and is an important product in parts of America. The fruit is borne in a dense head which does not bend over at maturity.

The empty glumes are somewhat shorter than the fruit and the flowering glume is not awned. The caryopsis is white or red according to the variety, nearly globular, about 4 mm. in diameter and separates from the glumes in threshing.

In microscopic structure Kaffir corn, aside from the absence of chaff, differs from the broom corns and sugar sorghums chiefly in that the perisperm is not evident either in cross-section or in surface preparation, and in that the hypoderm is more strongly developed, often consisting of three layers of thick-walled cells.

White milo maize is but a subvariety.

BIBLIOGRAPHY.

See Broom Corn, p. 103.

DURRHA.

Brown durrha, white durrha or Jerusalem corn, and yellow milo maize are forms of *Andropogon Sorghum* var. *durra* (Forskal) Hackel, differing from each other chiefly in the color of the caryopsis. They are grown to some extent in America for the grain, which is used as food for both cattle and poultry. The plants reach the height of 2 to 3 meters, but as the dense heads approach maturity, the rachis below them bends over, forming a goose-neck.

Both of the empty glumes are obtuse, densely hairy, and about half the length of the large, flattened, more or less lenticular caryopsis, which is 5 to 6 mm. long and of about the same breadth. The flowering glume of white durrha is awned, but that of red durrha and yellow milo maize is awnless. As found in the market, the grain is usually free from all envelopes.

Although to the naked eye the fruits of the three varieties are much alike except in color, under the microscope they show one marked difference. In brown durrha the perisperm or nucellar layer is always strongly developed, whereas in the white and yellow varieties this layer is not evident.

The other parts of the fruit are much the same as described under broom corn, but the outer layers of the endosperm normally contain only aleurone grains.

BIBLIOGRAPHY.

See Broom Corn, p. 103.

RICE.

Rice (*Oryza sativa* L.), although not strictly a bread grain, furnishes daily food for more human beings than any other cereal. It is the chief food product in China, where it has been cultivated for nearly 5000 years, also in Japan, India, and other Oriental countries. Its culture has extended from the East to all the warmer regions of the globe.

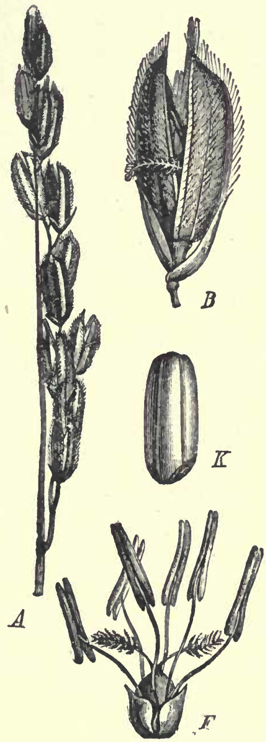


FIG. 72. Rice (*Oryza sativa*). *A* panicle; *B* single fruit with chaff; *K* naked fruit; *F* flower. (NEES.)

The inflorescence is in panicles (Fig. 72, *A*) made up of single-flowered spikelets (*B*), each with two minute empty glumes, a thick, awned, conspicuously five-ribbed flowering glume, and an equally thick, three-ribbed palet, both the latter being strongly compressed and keeled. The flowering glume and palet are dull and lusterless, harsh and rasping to the touch, owing to numerous longitudinal striations with transverse markings, which, together with coarse hairs, are readily seen under a lens. The awn is seldom found on the threshed grain. The flattened fruit or caryopsis (*K*) is oblong, about 8 mm. long with blunt base and apex. The relief of the glumes is impressed on the surface, forming longitudinal grooves and ridges. The germ is situated on the dorsal edge at the base.

HISTOLOGY.

Flowering Glume and Palet. Owing to the silica in the epidermis, rice glumes cannot be readily sectioned until after they have been soaked for some time in alkali. Maceration in Schulze's fluid serves to isolate the elements.

1. *The Outer Epidermis* (Figs. 73 and 74, ep^1) consists of parallel longitudinal rows of large, thick-walled cells, square in general outline, with highly characteristic, very deeply sinuous side walls. Focusing on the outer walls, these side walls are seen to be compoundly sinuous.

Stiff dagger-shaped hairs (t^1) up to 500 μ long (usually 150–250 μ) and 40 μ in diameter at the base are scattered over the surface, being

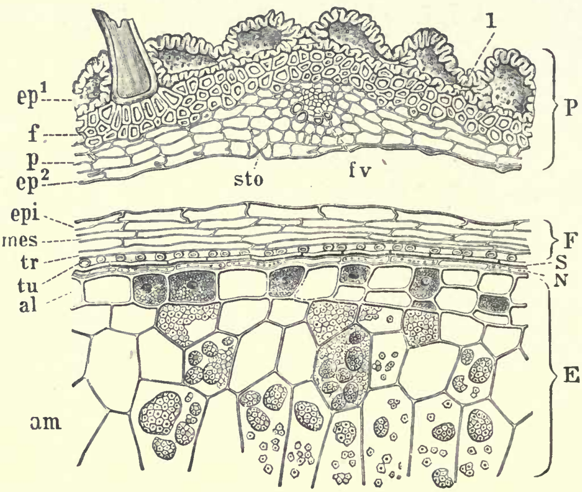


FIG. 73. Rice. Cross section of palet and outer portion of fruit. *P* palet consists of ep^1 outer epidermis with hair, *f* hypoderm fibers, *p* spongy parenchyma with *fv* bundle, and ep^2 inner epidermis with *sto* stoma; *F* pericarp consists of *epi* epicarp, *mes* mesocarp, *tr* cross cells, and *tu* tube cells; *S* spermoderm; *N* perisperm; *E* endosperm consists of *al* aleurone cells, also starch cells. ×160. (WINTON.)

especially abundant and also longest on the ribs and near the apex. The walls are 5–9 μ thick.

2. *The Hypoderm* (*f*) consists of a double or triple layer of longitudinally-extended sclerenchyma fibers. In the outer layers, the fibers are strongly thickened and often have comb-like outgrowths, which join them one with another or with the epidermis. The inner fibers are thinner walled and have outgrowths only on the outer sides.

3. *Spongy Parenchyma* (*p*). Two, sometimes more, layers of spongy parenchyma, through which run the bundles, form the mesophyl. The cells are rectangular, with thin wavy walls. Intercellular spaces occur, not only at the angles, but also between the surfaces of the walls.

4. *Inner Epidermis* (ep^2). In cross-section, this layer of collapsed cells appears as a hyaline, striated membrane. Surface preparations

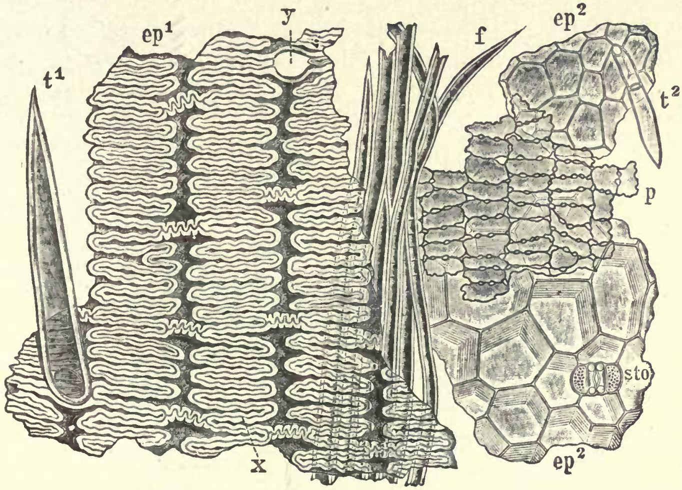


FIG. 74. Rice. Layers of palet in surface view. ep^1 outer epidermis with *x* sinuous cells, t^1 hair, and *y* hair scar; *f* hypoderm fibers; *p* spongy parenchyma; ep^2 inner epidermis with *sto* stoma and t^2 hair. × 160. (WINTON.)

show that the cells over the bundles are elongated, but in other parts are more or less cubical. The cell-walls are thin and marked with delicate striations. Between these cells occur one- to three-celled (usually two-celled) very thin-walled hairs, also stomata, consisting of two peculiar guard cells and two somewhat larger companion cells with protoplasmic contents.

Pericarp (Fig. 73, *F*; Fig. 75). Sections are cut after removing the hulls and soaking for some hours in water. Fragments for surface examination are obtained by boiling the grain for a few moments in 1¼ per cent alkali, plunging in dilute acetic acid, and removing the outer skin, which readily separates after this treatment.

1. *Epicarp* (*epi*). The outer layer of the fruit is the easiest found and the most characteristic. Unlike the epicarp of all the other cereals, the cells are transversely elongated, with curious, wavy, end walls. They are 120–500 μ long and 30–100 μ wide, and are arranged side by side in rows.

2. *Mesocarp* (*mes*). Several layers of more or less compressed cells, indistinctly seen in transverse section, underlie the epicarp. In the first layer or two these cells are much like the cross cells of barley, but in the

inner layers they are more elongated, passing into the vermiform cells of the next layer.

3. *Cross Cells* (*tr*). As all the cells between the epicarp and tube cells are transversely elongated, increasing in length but decreasing in breadth from without inward, a sharp classification into two layers is obviously impossible. The cells of the inner layer, here designated as

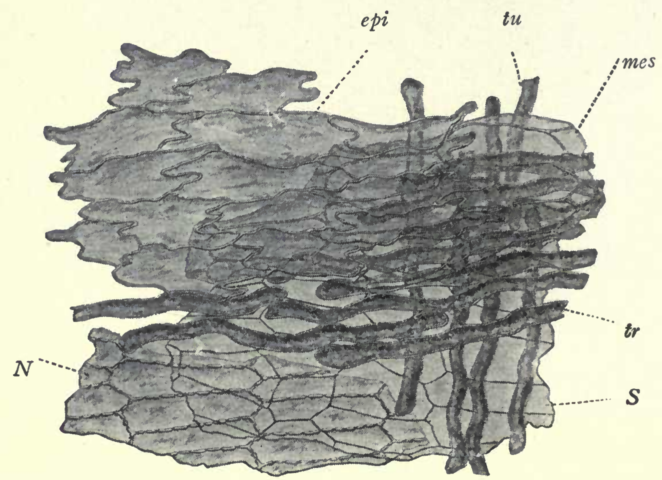


FIG. 75. Rice. Bran coats in surface view. *epi* epicarp; *mes* mesocarp; *tr* cross cells; *tu* tube cells; *S* spermoderm; *N* perisperm. ×300. (WINTON.)

cross cells, are strikingly distinct from the cross cells of wheat, rye, barley, and oats, but resemble closely those of maize, sorghum, and millet. They range in length up to 500 μ, but are only 4–6 μ broad. As a rule they are nearly straight, but in parts they are bent and even branching. They occur either united in a close layer or detached.

Tube Cells (*tu*). The detached vermiform cells resemble strikingly those of the last layer, but are narrower, being but 3–5 μ broad. They are the only cells of the pericarp, spermoderm, or perisperm that are not transversely elongated.

Spermoderm (Figs 73 and 75, *S*). Cross-sections, previous to treatment with reagents, show only an indistinct structureless line between the tube cells and aleurone layer; but after heating with potash, washing in dilute acetic acid, and staining with chlorzinc iodine, the cuticle of the spermoderm is evident as a thin, yellow line, and the perisperm as a dark blue layer. After the removal of the tnin skin forming the pericarp, as already described, a second, thicker skin, consisting chiefly of spermoderm, perisperm, and aleurone cells may be separated by scraping. The spermoderm is recognized by the thin cell-walls and the bright yellow color due to the thick cuticle. The more or less transversely or diagonally elongated cells resemble those of wheat and other cereals, but form only one layer.

Perisperm (Figs. 73 and 75, *N*). As has been noted in the preceding paragraph, remains of the nucellus may be seen in section after treatment with potash and staining with chlorzinc iodine. In carefully prepared mounts the reticulated radial walls are evident. These cells are easily seen in surface view in mounts prepared as above described, and are distinguished from the cells of the spermoderm by the beaded appearance of the radial walls, due to reticulations, and their dark blue color. The cells are transversely elongated and are side by side in rows.

Endosperm (Fig. 73, *E*). 1. *The Aleurone Cells* (*al*) are rounded polygonal, 25–40 μ in diameter, with uncommonly thin walls.

2. *Starch Parenchyma.* The thin-walled cells contain starch grains (Fig. 76) 2–10 μ in diameter often united into oval aggregates containing

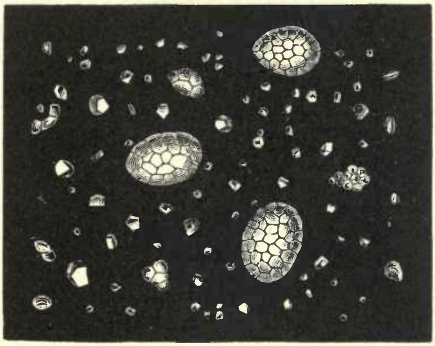


FIG. 76. Rice Starch. ×300. (MOELLER.)

from two to upward of a hundred grains. Grains from the center of a large aggregate have only flat facets, but those from the outer portion are curved on the exposed surfaces. Perfectly round grains arc rare. In commercial rice-starch one seldom finds aggregates, since they are usually broken up in the process of manufacture. The grains shows distinct crosses with crossed Nicols, the hilum being centrally located.

DIAGNOSIS.

Whole Rice. Rice is largely used as a human food in the form of the whole grain divested of the chaff, pericarp, spermoderm, the larger part of the germ, and some of the aleurone layer.

Mill Products. *Rice Flour* and various other mill products are used to a limited extent in preparing infant and invalid foods, griddle cakes, puddings, etc.

In all the products above named, the microscopic elements are starch grains (Fig. 76), occurring as individuals or in aggregates, aleurone cells, and occasional fragments of other parts of the grain.

Flaked Rice is a breakfast preparation, cooked ready for use. The starch grains are much distorted.

Rice-starch (see p. 652).

Rice By-products. Two by-products are obtained in preparing commercial rice: first, hulls or, more correctly, glumes and palets, and second, bran or middlings, consisting of the pericarp, spermoderm, germ, and fragments of the aleurone layer.

Rice Hulls are useful as packing for eggs, bottles, etc. Owing to their harshness, as well as the lack of food elements, they are not fit for cattle foods. Ground rice hulls are, however, used for adulterating not only fodders, but cocoa, pepper, and other human foods. Fragments of sufficient size may be identified under a lens by the striations. If, while held by a needle, they are scraped with a scalpel, their rough, silicious nature is evident. Under the microscope, after treatment with alkali or macerating, the nearly square epidermal cells (Fig. 74, ep^1) with thick deeply zigzag walls and the broad dagger-shaped hairs (t^1) are highly characteristic.

Rice Bran is a valuable fodder and is a common adulterant of spices and other foods. It is composed not only of the elements of the pericarp, spermoderm, and germ, but also of aleurone cells and starch parenchyma, and often is contaminated with hulls.

The most characteristic elements of the fruit are the epicarp cells (Fig. 75, *epi*) with zigzag end walls, but cross cells and tube cells also aid in identification.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Böhmer (6, 23); Hanausek, T. F. (16, 17); Harz (18); Hassall (19); Leach (25); Macé (26); Moeller (29); Planchon et Collin (34);

Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (43, 45); Wittmack (10).

Also see Bibliography of Wheat, pp. 72 and 73.

BURCHARD: Reis und Reisabfälle. Landw. Vers.-Stat. 1896, 48, 111.

v. HÖHNEL: Die anatomischen Verhältnisse der Reisspelze. Haberland's Wissensch.-prakt. Unters. auf dem Gebiete des Pflanzenbaues. I, 149.

STREET: Rice Hulls. New Jersey Agrl. Expt. Sta. Bull. 160, 1902.

OATS.

Oats (*Avena sativa* L.) are not only a valuable food for horses and other cattle, but also for the human family. For generations this cereal has been one of the chief articles of diet in Norway, Scotland, and Ireland, and within the last generation oat preparations have come into extensive use in America.

The numerous varieties are grouped under two races: panicled oats, with loose inflorescence, and banner oats (*A. orientalis* Schreb.), with one-sided, contracted panicles. Belonging to both races, are naked and chaffy, awned and awnless varieties. Wild oats (*A. fatua* L.), with

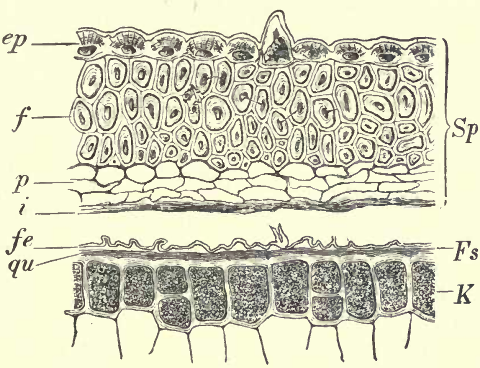


FIG. 77. Oats (*Avena sativa*). Cross section of flowering glume and fruit. *Sp* flowering glume consists of *ep* outer epidermis, *f* hypoderm fibers, *p* spongy parenchyma, and *i* inner epidermis; *Fs* pericarp consists of *fe* epicarp and *qu* cross cells; *K* aleurone cells of the endosperm. ×160. (MOELLER.)

geniculate awns, a common weed in grain fields, is believed by many botanists to have been the parent of the principal varieties in cultivation.

The two or more flowered spikelets are subtended by two large, membraneous, empty glumes, which are left on the straw after threshing. In the common varieties, each grain is closely enveloped by the smooth, rounded, silicified, five or more veined, but not ribbed flowering glume, and the two-nerved, thin, palet. The flowering glume has narrow, thin, edges; the palet, broad, membraneous wings which clasp the fruit. The

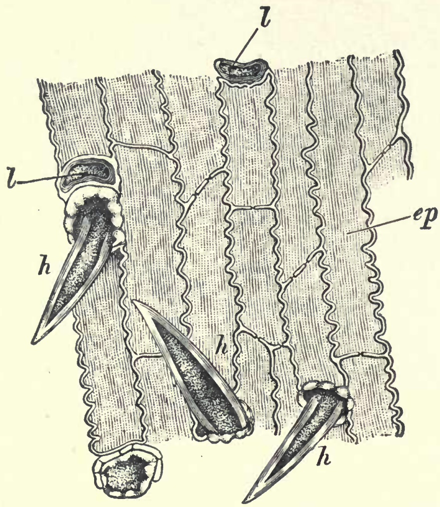


FIG. 78. Oats. Outer epidermis from the margin of the flowering glume. *h* hairs; *l* crescent-shaped cells. ×300. (MOELLER.)

awn of the flowering glume, when present, is broken off in cleaning the

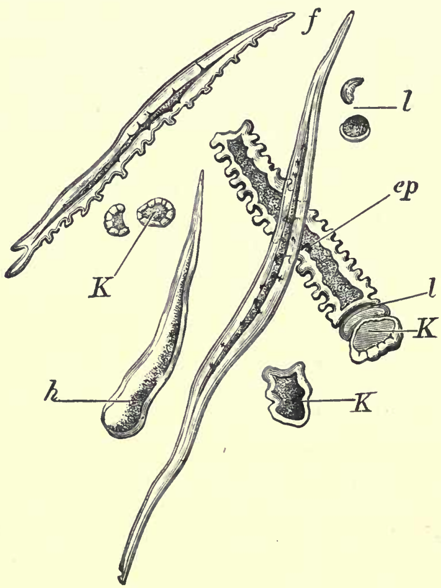


FIG. 79. Oats. Elements of chaff (flowering glumes and palets) isolated by maceration. *ep* elongated cells, *l* crescent-shaped cells and *K* silica cell, all of the outer epidermis; *h* hair; *f* hypoderm fibers. ×160. (MOELLER.)

grain. Freed of the chaff, the grain is spindle-shaped, with a silky-hairy shallow groove on the ventral side. The germ is about one-third the length of the fruit.

HISTOLOGY.

Flowering Glume. 1. *The Outer Epidermis* (Fig. 77, *ep*) consists of elongated cells with thick, wavy walls, twin cells (one of which is usually crescent-shaped), and circular cells. On the body of the glume the cell-walls are often thicker than the cavity (Fig. 79, *ep*) while on the edges (Fig. 78) they are much thinner. Hairs occur on the edges, being most

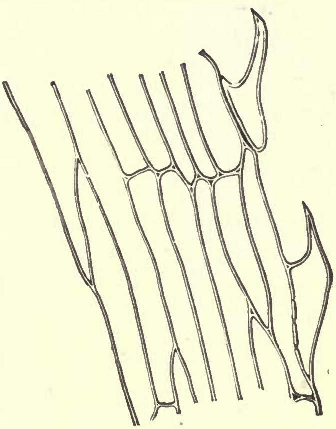


FIG. 80. Oats. Cells and hairs from membranous margin of flowering glume. ×160. (MOELLER.)

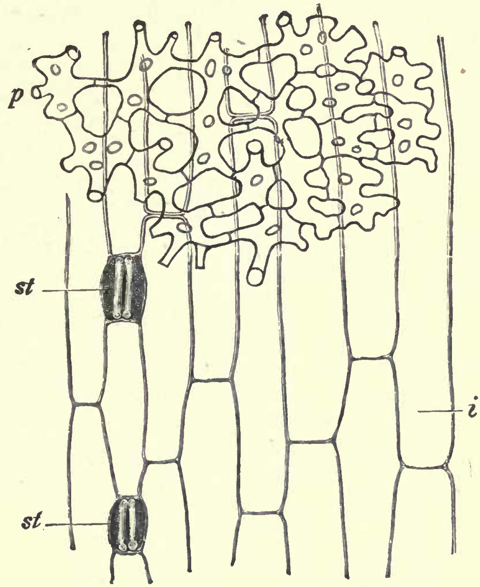


FIG. 81. Oats. Inner layers of chaff (flowering glume or palet), in surface view. *p* spongy parenchyma; *i* inner epidermis with *st* stomata. ×300. (MOELLER.)

numerous near the apex. They are mostly rigid, thick-walled, dagger-shaped, broad at base (15–20 μ) and seldom exceed 60 μ in length. Some at the very edge are thin-walled, with a slight curve toward the end, giving them a peculiar, hooked appearance (Fig. 80).

2. *Hypoderm Fibers* (Figs. 77 and 79, *f*), for the most part in 4–10 layers, form a dense, hard coat. The individuals often exceed 1 mm. in length, and have thick, sparingly porous walls. As may be seen after maceration, the walls adjoining the epidermis are often toothed.

3. *The Spongy Parenchyma* (Figs. 77 and 81, *p*) is distinguished from the corresponding layer of other cereals by the star-shaped form of the cells.

4. *The Inner Epidermis* (*i*) consists of thin-walled cells and stomata.

The Palet. The middle portion of the palet has practically the same structure as the flowering glume, except that the hypoderm layer is thinner; but the membraneous wings have an outer epidermis made up of thin-walled cells, and a rudimentary hypoderm or else no hypoderm whatever. Near the keels and parallel to them are rows of stomata, and on the keels are numerous stiff, thick-walled, pointed hairs about 15 μ in diameter at the base and upward of 100 μ long. As the palet often breaks or bends on the keels these hairs form a highly characteristic saw-tooth edge.

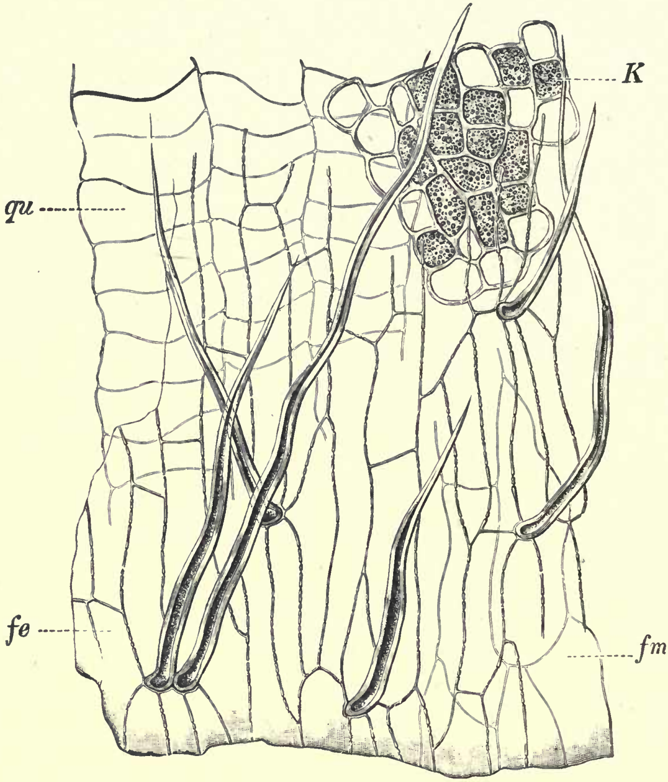


FIG. 82. Oats. Bran coats in surface view. *fe* epicarp with long hairs; *fm* mesocarp; *qu* cross cells; *K* aleurone cells. $\times$ 160. (MOELLER.)

Pericarp (Figs. 77 and 82). In cross-section the pericarp and spermoderm do not show details of structure. The following characters may be observed in surface view:

1. *Epicarp.* The cells on the body of the grain are longitudinally elongated, with thin, porous side walls, but at the apex and base are nearly

isodiametric. The long hairs which clothe the apex often exceed 200 μ in length. They are usually broadest in the middle (about 20 μ), tapering toward both ends. The base is sometimes so narrow as to be hardly distinguishable from the apex.

2. *The Mesocarp* or *Middle Coat* (*fm*) is ill-defined.

3. *Cross Cells* (*qu*). The thin-walled, inconspicuous cells are arranged side by side in rows.

The Spermoderm and Perisperm are not evident in the ripe grain.

Endosperm (Figs. 76 and 82). 1. *The Aleurone Layer* (*K*) is commonly one cell-layer thick. The cells are 20–60 μ, and have thinner walls (double walls 5 μ or less) than in wheat, rye and barley.

2. *Starch Parenchyma.* The large, thin-walled cells contain starch grains (Fig. 83) which for the most part are polygonal, and are collected

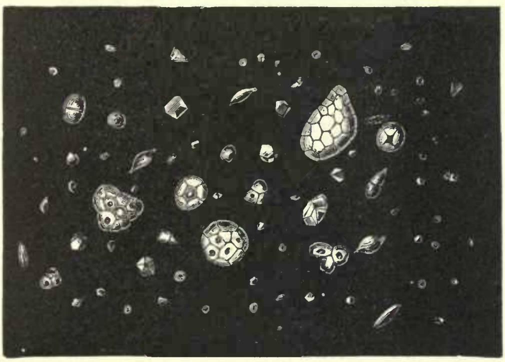


FIG. 83. Oat Starch. ×300. (MOELLER.)

in ellipsoidal or rounded aggregates (up to 60 μ) of from two to many grains. Among the simple grains are characteristic spindle-shaped forms. The individual grains seldom exceed 10 μ in diameter, and are commonly much less.

DIAGNOSIS.

Oats are commonly fed to horses and other farm animals without removing the chaff, and often without grinding. Ground oats are frequently mixed with other cereal products, particularly those containing less fibrous matter. Provender, a mixture of ground oats and maize, is one of the commonest horse feeds in the United States.

The elements of chief importance in diagnosis are: first, the smooth, rounded (not ribbed as in barley) flowering glume, with an epidermis (Fig. 79, *ep*) of thick, wavy-walled, elongated cells, circular cells and twin cells, and with star-shaped (not rectangular as in other cereals) spongy parenchyma cells (Fig. 81, *p*); second, the palet of more delicate structure, having keels barbed with coarse hairs, forming saw-toothed edges; third, the epicarp with long, slender hairs (Fig. 82), often narrowed at the base; fourth, the rounded aggregates of polygonal starch grains and spindle-shaped forms (Fig. 83).

Oatmeal, Rolled Oats, and similar "breakfast cereals," contain all the above elements except those of the chaff, though in some of these products the starch grains have been distorted by cooking.

Oat By-products, consisting chiefly of chaff, are obtained in the manufacture of breakfast cereals and are used in mixed cattle foods. They are inferior in nutritive value, being rich in fiber but poor in protein, fat and starch. The glumes and palets are distinguished from the corresponding parts of barley by the characters above named.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Berg (3); Böhmer (6, 23); Hanausek, T. F. (16); Harz (18); Hassall (19); Leach (25); Macé (26); Moeller (29); Planchon et Collin (34); Schimper (37); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (43, 45); Wittmack (10).

Also see Bibliography of Wheat, pp. 72 and 73.

EMMERLING: Ueber eine einfache Unterscheidungsweise von Gersten- und Haferspelzen. Landw. Vers.-Stat. 1898, **50**, 1.

WHITE: Note on the Use of Maize as an Adulterant of Oatmeal. Analyst. 1895, **20**, 30.

COMMON MILLET.

Millet (*Panicum miliaceum* L.), an ancient cereal, is still extensively cultivated for grain in India, China, and Japan, and to some extent in Russia and other parts of Europe. In America it is grown only for green fodder and hay.

The nearly globular fruit is tightly clasped by the flowering glume and palet, the whole forming an oval grain 3 mm. long and 2 mm. broad. Both envelopes are of a uniform buff or straw color and are smooth and lustrous.

HISTOLOGY.

Flowering Glumes and Palet. *The Outer Epidermal* cells on the palet and the central part of the glume are isodiametric or somewhat elongated, with compoundly sinuous side and end walls; on the edges of the glume they are more elongated, with straight end walls. Both forms have smooth outer walls and are without colored contents.

The Hypoderm Fibers, rectangular parenchyma cells without intercellular spaces, and the inner epidermis also of rectangular cells, are the same as in the glumes and palet of Setaria.

The Caryopsis agrees in structure with that of *Setaria viridis* and *S. Italica*, except that the aleurone cells are 25–50 μ in diameter, whereas in Setaria they seldom exceed 20 μ. Vogl has shown that on treatment

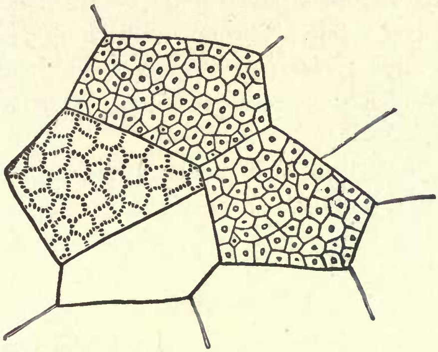


FIG. 84. Common Millet (*Panicum miliaceum*). Starch cells of endosperm showing (at the left) beaded network remaining after treatment with alkali. (VOGL.)

with alkali the starch grains dissolve, leaving a beaded network corresponding to the form of the grains (Fig. 84).

DIAGNOSIS.

The chief products of millet are grits and the chaff and other by-products obtained in the preparation of grits.

Millet grits contains starchy matter, large aleurone cells, and fragments of other bran elements.

In chaffy by-products, the glumes and palets are distinguished from those of chaffy wheats, barley, oats, rice, maize, darnel, and chess by the absence of hairs, and of twin cells, and also by the rectangular parenchyma cells without intercellular spaces; from those of German millet by the absence of wrinkles on the outer epidermis, and from those of green foxtail by the absence of both wrinkles and patches of brown tissues.

BIBLIOGRAPHY.

HANAUSEK, T. F.: Ueber die Matta. Ztschr. Nahr.-Unters. Hyg. 1887, **1**, 24.

NETOLITZKY: Mikroskopische Untersuchung gänzlich verkohlter vorgeschichtlicher Nahrungsmittel aus Tirol. Ztschr. Unters. Nahr.-Genussm. 1900, **3**, 401.

VOGL: Die wichtigsten vegetabilischen Nahrungs- und Genussmittel. Berlin u. Wien, 1899, 135.

GERMAN MILLET.

There is good evidence that German millet or Hungarian grass (*Setaria Italica* Beauv., *S. panis* Jessen) was the chief cereal of the lake dwellers and other prehistoric races. In China as early as 2700 B.C. it ranked with rice as one of the staple crops, and is still an important cereal in the East. In other parts of the world it is grown largely for hay or for poultry food. Since German millet is regarded as but a form of green foxtail (*Setaria viridis*) developed by cultivation, it is not surprising that the fruits of the two agree closely both in macroscopic and microscopic structure.

The glumes and palets are of a yellow or buff color, which aids in distinguishing them from the spotted or dark envelopes of green foxtail. In other respects the two grains are not distinguishable.

BIBLIOGRAPHY.

HANAUSEK, T. F.: Ueber die Matta. Ztschr. Nahr.-Unters. Hyg. 1887, **1**, 24.
VOGL: Die wichtigsten vegetabilischen Nahrungs- u. Genussmittel. Berlin u. Wien, 1899, 135.

GREEN FOXTAIL.

Green foxtail (*Setaria viridis* Beauv., *Chaetochloa viridis* (L.) Scribn.) is a troublesome weed in both continents, particularly in the grain fields of the northwestern states of the United States. The seed has been found in American screenings in quantities varying up to 11.6 per cent.

The inflorescence is in dense, bristly spikes, or rather spiked panicles, 4–10 cm. long. Each spikelet consists of two empty glumes and two flowers, one perfect with coriaceous transversely wrinkled glume and palet, the other staminate with membraneous envelopes (Fig. 85). At the base of the spikelet are from two to four upwardly barbed bristles varying in length up to 8 mm.

HISTOLOGY.

Empty Glumes and Glume of Sterile Flower (Fig. 85, g^1, g^2 and gf^1). The lower empty glume is three-veined and less than 1 mm. long; the upper empty glume and the glume of the staminate flower are five-veined and 2 mm. long. In microscopic structure the three are practically identical.

1. *Outer Epidermis* (Fig. 86). Characteristic of this layer are the elongated cells with sinuous side walls and longitudinal rows of pits so arranged that one pit occurs in each concave bend of the wall. On the middle portion of the mature glume each of these pits is so large that it fills completely the bend of the wall and in addition has a thickened border, half of which coincides with the cell-wall, thus giving the tissue a lace-like appearance. This structure is optically delusive, the pit

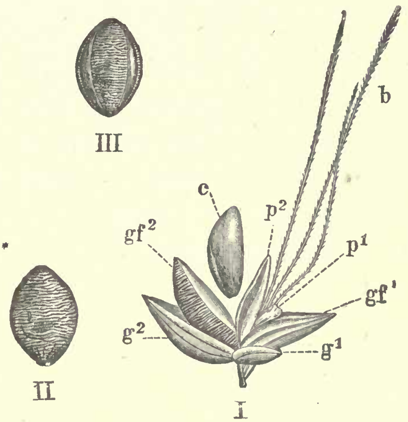


FIG. 85. Green Foxtail (*Setaria viridis*). *I* spikelet with ripe fruit: g^1 lower empty glume; g^2 upper empty glume; gf^1 glume and p^1 palet of staminate flower; gf^2 glume and p^2 palet of fertile flower; *c* fruit or caryopsis; *b* bristles. *II* and *III* caryopsis enclosed by flowering glume and palet. ×8. (WINTON.)

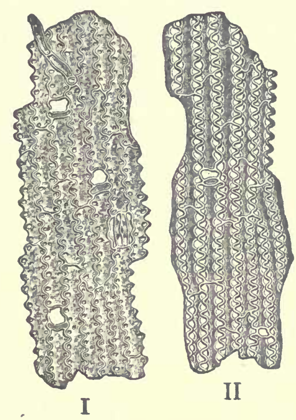


FIG. 86. Green Foxtail. Outer epidermis of the glume of the staminate flower. *I* at the edge; *II* in the middle. ×300. (WINTON.)

borders often appearing to be the cell-walls, but is resolved by careful focusing and comparison with the tissue in earlier stages of growth.

In addition to these elongated cells, pairs of short cells, one isodiametric, probably a hair-scar, the other more or less crescent-shaped, occur here and there, and less frequently stomata and thin-walled one- to three-jointed hairs.

2. *Mesophyl.* Only about the nerves and the basal portions of the glumes is this coat evident. It has no diagnostic importance.

3. *The Inner Epidermis* is composed of elongated cells with straight walls.

Palet of Staminate Flower (Fig. 85, p^1). Within the glume of the staminate flower is the palet, a hyaline scale only 1 mm. or less long with a notch at the end. In general structure, it is much the same as the other thin envelopes, but the cell-walls are thinner.

1. *Outer Epidermis.* The narrow, elongated cells are wavy in outline, but pits are lacking or are indistinct. Isodiametric cells and thin-walled jointed hairs also occur.

2. *Inner Epidermis.* Except at the base, where traces of mesophyl are sometimes evident, the inner epidermis immediately underlies the outer epidermis.

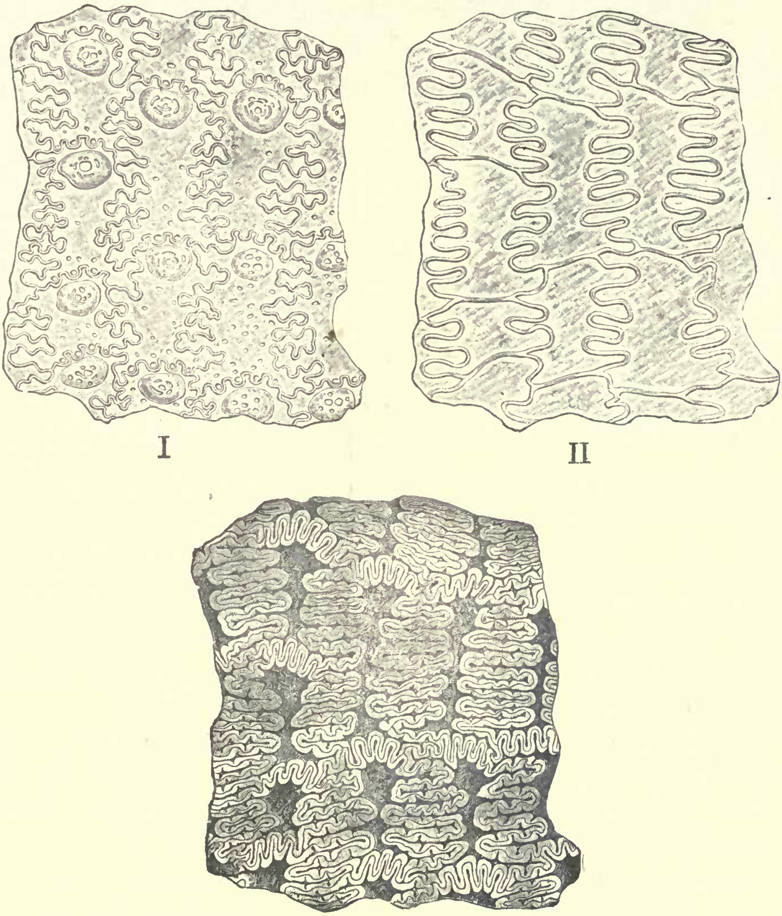
Glume and Palet of Perfect Flower (Fig. 85, gl^2, p^2). Both the glume and the palet of the fertile flower closely envelop the grain at maturity, the former being strongly convex, the latter flat except on the edges which clasp about the caryopsis. At the time of flowering these envelopes are thin and of a green color, but at maturity they are coriaceous, silicified and of a brown or mottled color. Under a lens, numerous transverse wrinkles are evident on the glume and on the middle or flat portion of the palet, the lateral portions of the latter which clasp the caryopsis being smooth and shining.

1. *Outer Epidermis* (Figs. 87, 88, 89). Throughout the glume and on the middle portion of the palet, the cells are isodiametric or moderately

Fig. 87. Green Foxtail. Outer epidermis of glume of fertile flower, showing the smooth edge and the wrinkled and mottled central portion. (Winton.)

elongated and are arranged not only in longitudinal rows but also in irregular transverse rows, the wrinkles being formed by the outward bending of the cells at the end walls and the inward bending halfway between.

At the time of flowering, it may be seen that at the outer surface the end walls are sinuous and the side walls are compoundly sinuous (Fig. 88, *I*), but further inward the end walls are nearly straight and the side walls are simply, not compoundly sinuous (Fig. 88, *II*). At the end of each



I II

III

Fig. 88. Green Foxtail. Outer epidermis from middle of glume of fertile flower. *I* Outer surface and *II* inner surface soon after blooming. *III* Outer surface when in fruit. ×300. (Winton.)

cell nearest the apex of the envelope, a cuticular wart bearing a group of pits is usually evident, particularly on the palet (Fig. 88, *I*). About these warts the adjoining end walls are more or less curved and the side walls are not so deeply sinuous. At maturity the cell cavity beneath the wart is conspicuous (on the palet nearly circular), but at the other end of the cell is narrow or not evident at all owing to the encroachment of the strongly thickened walls (Fig. 87; Fig. 88, *III*).

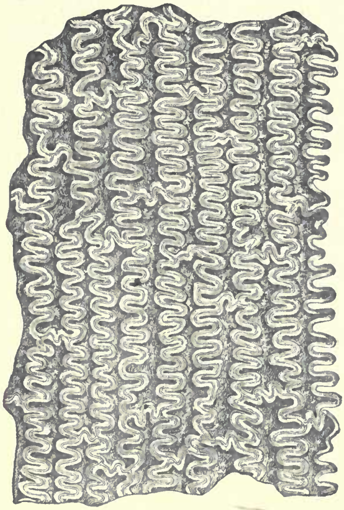


FIG. 89. Green Foxtail. Outer epidermis from edge of glume of fertile flower. ×300. (WINTON.)

The cell contents during the early stages of development are colorless, but later on usually become dark brown.

The epidermal cells on the lateral or smooth portions of the palet which clasp about the caryopsis are longer, narrower, and less complex than those already described (Fig. 89).

At maturity the wrinkles are usually 30–60 μ apart.

2. *The Hypoderm Fibers* may be readily isolated by treatment on the slide with caustic alkali. They vary in length up to 0.6 mm. and are often toothed at the margin.

3. *Mesophyl.* Rectangular parenchyma cells without intercellular spaces make up this layer. Numerous chlorophyl granules are present at the time of flowering.

4. *The Inner Epidermis* is composed of rectangular cells resembling those of the mesophyl. Both of these layers become more or less obliterated at maturity and are of no diagnostic importance.

Pericarp (Figs. 90 and 91). The ventral side is flat and has a dark colored spot, the remains of the hilum, near the base. Extending halfway from the base to the apex on the dorsal side is a groove, which marks the position of the embryo.

1. *Epicarp.* (*ep*). As in the outer epidermal layers of the floral envelopes the cells are elongated and wavy in outline. On the dark colored spot already referred to, the epidermal cells are more or less rectangular.

2. *The Cross Cells* (*q*) are similar to the tube cells in form, but are usually shorter, broader, and more irregular in shape.

3. *Tube Cells* (*sch*). These are 2–4 μ wide and often reach the length of 300 μ.

Perisperm (*N*). After treatment with alkali, this layer is clearly seen in surface view. The cells are of large size and have beaded walls.

Endosperm. 1. *Aleurone Layer* (*al*). The cells are 10–20 μ in diameter.

2. *Starch Cells* (Fig. 90, *s*). Polygonal starch grains with conspicu-

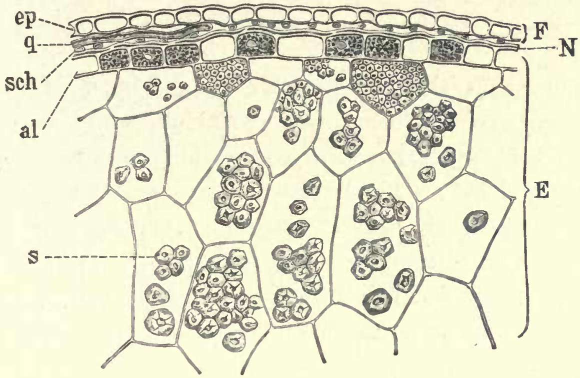


FIG. 90. Green Foxtail. Cross section of outer portion of fruit. *F* pericarp consists of *ep* epicarp, *q* cross cells, and *sch* tube cells; *N* perisperm; *E* endosperm consists of *al* aleurone cells and *s* starch cells. ×300. (WINTON.)

ous hilum fill the parenchyma cells of the endosperm. In the outer layers they are from 4–8 μ in diameter, but further inward they reach the maximum diameter of 18 μ.

After dissolving the starch with alkali, there remains a network of

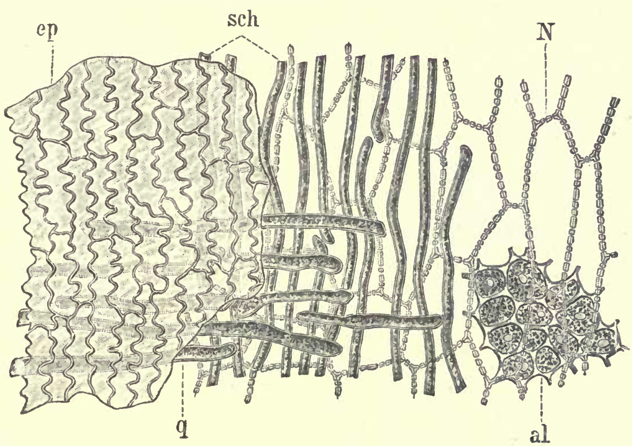


FIG. 91. Green Foxtail. Bran coats in surface view. *ep* epicarp; *q* cross cells; *sch* tube cells; *N* perisperm; *al* aleurone cells. ×300. (WINTON.)

threads containing conspicuous granules, which is very different from the network of homogeneous threads obtained from polygonaceous seeds.

In this respect, however, this fruit cannot be distinguished from the fruits of *S. glauca* Beauv., *S. panis* Jessen, *Panicum miliaceum* L. (see Vogl) and other species of *Panicum*.

DIAGNOSIS.

The membraneous glumes with pores in the bends of the walls (Fig. 86) and the coriaceous, transversely wrinkled, more or less spotted, envelopes of the fertile flower with compoundly sinuous, thickened cell-walls (Figs. 87 and 88) are highly characteristic of both green and yellow foxtail. These tissues are usually present in all stages of development.

The fruit elements are like those of common millet and German millet. Treatment with alkali brings out the structure of the fruit coats and perisperm, and serves to distinguish this fruit from the common cereals.

The starch is hardly distinguishable in form from the starch of bindweed, but the network remaining after treatment with alkali is beaded.

BIBLIOGRAPHY.

WINTON: Ueber amerikanische Weizen-Ausreuter. Ztschr. Unters. Nahr.-Genussm. 1903, 6, 433. Conn. Agr. Exp. Sta. Rep. 1902, 339.

YELLOW FOXTAIL.

The fruit of this species (*Setaria glauca* Beauv., *Chaetochloa glauca* (L.) Scribn.) is larger than that of green foxtail, the envelopes are also proportionately larger (with the exception of the upper empty glume which is but half the length of the spikelet) and the wrinkles on the glume of the fertile flower are more pronounced (Fig. 92).

I II

FIG. 92. Yellow Foxtail (*Setaria glauca*). Fruit inclosed in flowering glume and palet. *I* showing glume; *II* showing palet and edge of glume. ×8. (Photograph by W. E. BRITTON.)

In microscopic structure the fruits of the two species are identical. The floral envelopes are also much alike, the only distinction being in the distance apart of the wrinkles on the mature flowering glumes. In green foxtail this distance is usually 30–60 μ, but in yellow foxtail it is often 80–120 μ. Since this distinction does not apply to the immature glumes and since the wrinkles on the palets of the two species are practically the same, it is often difficult to identify the species in ground mixtures. Fortunately, identification of the genus is all that is usually required.

DARNEL.

The microscopic identification of darnel (*Lolium temulentum* L.) is important, as this fruit not only is one of the commonest impurities of European and Californian wheat, but also contains a poisonous principle (temulin) which renders it highly pernicious.

The four- to eight-flowered spikelet is inclosed within a strongly-nerved empty glume which, however, is seldom found in the threshed grain.

Adherent to each caryopsis is a flowering glume 6–8 mm. long, and a two-keeled palet of about the same size but of thinner texture (Fig. 93). The flowering glume is obscurely five-nerved, lobed at the end, and bears an upwardly-barbed awn often 15 mm. long. In cross section the caryopsis is U-shaped, owing to the deep groove on the ventral side.

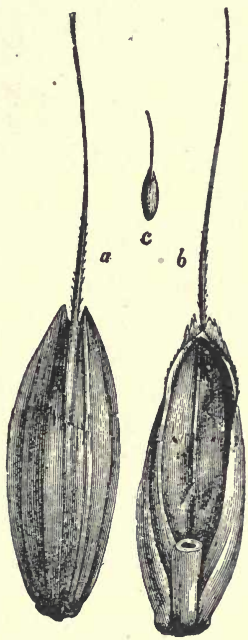


FIG. 93. Darnel (*Lolium temulentum*). *a* dorsal side and *b* ventral side, enlarged, *c* dorsal side, natural size. (NOBBE.)

HISTOLOGY.

The Flowering Glume, like the glumes of barley, oats, and other cereals, consists of four coats, some of which, however, are lacking on the margins and at the end.

1. *The Outer Epidermis* differs greatly in structure in different parts of the glume. At the margins (Fig. 94) it consists of straight-walled, elongated cells interspersed here and there with short lance-shaped hairs. On the greater part of the surface, however, the cells, as in barley and some other cereals, are of three kinds (Fig. 95): first, cells of wavy outline, into which the straight-walled cells at the margin pass; second, circular cells corresponding to the conical hair-cells of barley; third, exceedingly short, more or less crescent-shaped cells. Near the margins and on the veins, where they alternate with stomata, the cells of wavy outline are elongated; but in other parts they are very short, often being

broader than long. Although the cells are thick-walled, the walls are transparent, and the middle lamella is conspicuous, giving the impression

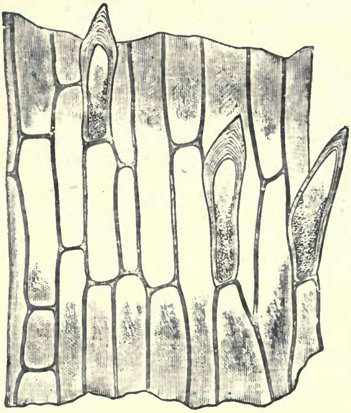


FIG. 94. Darnel. Margin of flowering glume showing lance-shaped hairs. ×300. (MOELLER.)

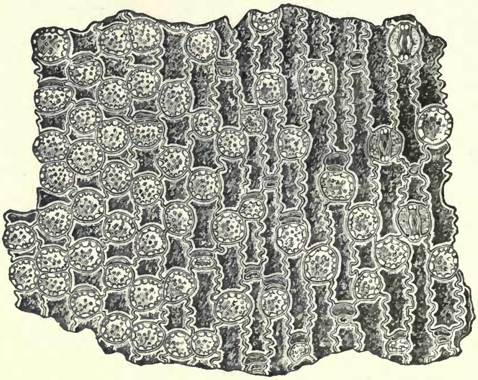


FIG. 95. Darnel. Middle portion of flowering glume. ×160. (WINTON.)

of thin-walled cells. Pores are few and inconspicuous. Near the margin the circular cells are small and are usually accompanied by crescent-shaped cells which often exceed them in size. On the greater part of the glume, however, the circular cells are much larger, often being 70 μ in diameter. Numerous pores are conspicuous, both in the radial and tangential walls. Often one, sometimes two, crescent-shaped cells accompany a circular cell.

Characteristic of this coat are the short, wavy cells and the numerous circular cells, the latter frequently exceeding in area the former.

2. *Hypoderm.* The fibers in this layer are much the same as in cereals. Fibers of similar structure also make up the ground tissue of the awn.

3. *Spongy Parenchyma.* The elements are more or less rectangular in shape, like those of the corresponding layer of barley, and are readily distinguished from the star-shaped elements of oats.

4. *Inner Epidermis.* This layer is made up of thin-walled cells and stomata, and is of no diagnostic importance.

The Palet lacks a well-developed hypoderm layer except beneath the keels.

The Outer Epidermis is much the same as that of the flowering glume, except that it is barbed on the keels with rigid, thorn-like hairs 150 μ or less in length (Fig. 96).

The Pericarp (Fig. 97, *F*; Fig. 98) consists of four coats, of which only two, the epidermis and cross cells, are fully developed.

1. *Epidermis* (*ep*). Cross sections of the mature seed show that this layer consists of collapsed, moderately thick-walled cells, which are

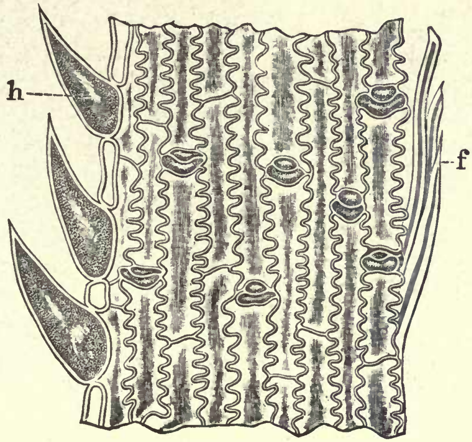


FIG. 96. Darnel. Keel of palet showing outer epidermis with *h* hairs, and *f* hypoderm fibers. ×160. (MOELLER.)

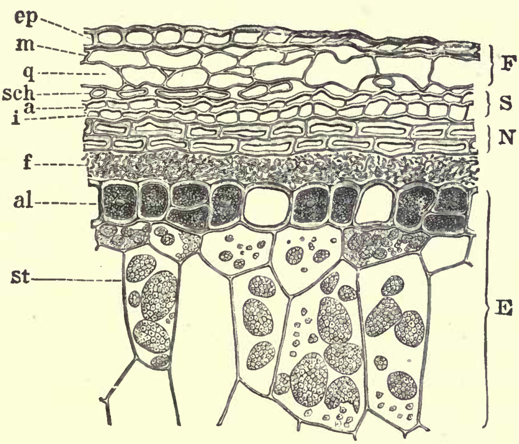


FIG. 97. Darnel. Cross section of outer portion of fruit. *F* pericarp consists of *ep* epicarp, *m* mesocarp, *q* cross cells, and *sch* tube cells; *S* spermoderm consists of *a* outer layer and *i* inner layer; *N* perisperm; *f* fungus layer; *E* endosperm consists of *al* aleurone layer, and *st* starch cells. ×160. (WINTON.)

best studied after heating with alkali. Seen in surface view, the cells at the apex of the seed are nearly isodiametric, but at other parts are elongated. The walls are indistinctly beaded.

2. *The Mesocarp* (*m*) is not developed on all parts of the seed, but is conspicuous on the angles. The cells vary greatly in shape and size,

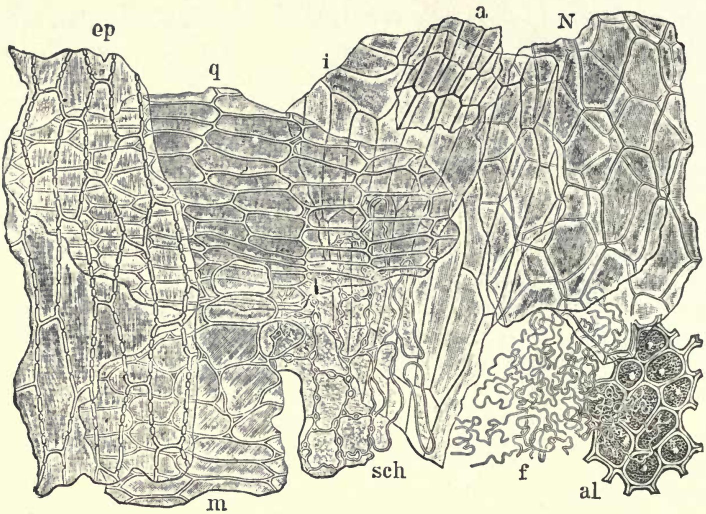


FIG. 98. Darnel. Bran coats in surface view. *ep* epicarp; *m* mesocarp; *q* cross cells; *sch* tube cells; *a* outer and *i* inner layer of spermoderm; *N* perisperm; *f* fungus layer; *al* aleurone cells. ×160. (WINTON.)

some being irregularly isodiametric, others transversely elongated, resembling the cells of the next layer.

3. *Cross Cells* (*q*). Especially striking are the cells of this layer, which resemble the cross cells of barley. The side walls are indistinctly beaded.

4. *Tube Cells*, spongy parenchyma, and various intermediate forms (*sch*) make up the interrupted inner layer of the pericarp.

Spermoderm (*S*). The cells are for the most part elongated and are often diagonally arranged with reference to the axis of the fruit. In transverse sections this coat often separates from the pericarp on the one hand and the perisperm on the other. Examined in water, only one cell layer (the inner) is evident: but successive treatments with 5 per cent alkali, dilute acetic acid and chlorzinc iodine, bring out two layers.

1. *The Outer Layer* (*a*) is made up of thin-walled cells with cuticularized outer walls. Treated as above described, the cuticle is colored yellow-brown, the radial and inner walls, blue.

2. *The Inner Layer* (*i*) is not only thicker than the outer, but the cells are thicker-walled and, in addition, swell greatly with alkali. These

swollen walls are stained deep blue by chlorzinc iodine, thus differentiating them from the yellow-brown cuticle on the inner wall.

Perisperm (*N*). Characteristic of this seed is the perisperm, consisting usually of two cell layers. In cross section these cells are rectangular with swollen walls; in surface view, as may be seen after soaking for a long time in dilute alkali, they are irregularly polygonal or more or less elongated.

Fungus Layer (*f*). In most specimens a layer of fungus threads 20 μ thick is present between the perisperm and the aleurone layer. So commonly is this fungus present in darnel grown in Europe, that it is of no little value in identifying the grain; but it remains to be determined whether in California, where the plant is a pest in wheat fields, the fungus is also a common accompaniment. After treatment with alkali this layer is stained bright yellow by zinc chloride iodine.

Endosperm. 1. *The Aleurone Cells* (*al*) vary from less than 20 to 40 μ in diameter.

2. *Starch Parenchyma* (Fig. 97, *st*). The thin-walled cells contain small polygonal grains 3–7 μ in diameter. The individual starch grains are not distinguishable from the grains of rice and oats, and like the latter often occur in aggregates of various sizes.

DIAGNOSIS.

The characteristic elements of darnel are the epidermis (Fig. 95) of the glumes and palets, and the fungus layer (Fig. 98, *f*). The cross cells (*q*) and starch grains (Fig. 97, *st*) aid in identification, though the former may be readily confounded with the corresponding tissue of barley and the latter with the starch grains of oats. The spongy parenchyma of the flowering glume resembles that of barley, but is readily distinguished from the spongy parenchyma of oat glumes.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Macé (26); Moeller (29); Villiers et Collin (42); Vogl (45).

HANAUSEK, T. F.: Vorläufige Mittheilung über den von A. Vogl in der Frucht von *Lolium temulentum* entdeckten Pilz. Ber. deutsch. bot. Ges. 1898, **16**, 203.

NESTLER: Ueber einen in der Frucht von ***Lolium temulentum*** L. vorkommenden Pilz. Ber. deutsch. bot. Ges. 1898, **16**, 207.

VOGL: Mehl und die anderen Mahlproducte der Cerealien und Leguminosen. Ztschr. Nahr.-Unters. Hyg. 1898, **12**, 25.

WINTON: Anatomie der Früchte des Taumellolches und der Roggentrespe. Ztschr. Unters. Nahr.-Genussm. 1904, **7**, 321. Conn. Agr. Exp. Sta. Rep. 1903, 165.

CHESS.

Chess (*Bromus secalinus* L.) is one of the commonest weeds of grain fields, both in Europe and America, and the fruit is a common constituent of uncleaned grain, screenings, and various by-products.

The fruit when invested by the flowering glume and palet closely resembles darnel, but the awn of the flowering glume is short or absent.

HISTOLOGY.

Flowering Glume. The structure throughout is much the same as in darnel, but the cells of the outer epidermis (Fig. 99) are much more

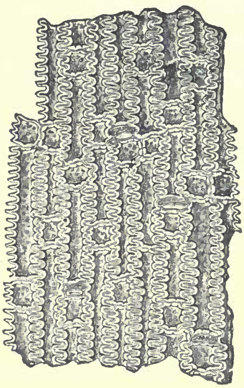


FIG. 99. Chess (*Bromus secalinus*). Outer epidermis of flowering glume in surface view. ×160. (WINTON.)

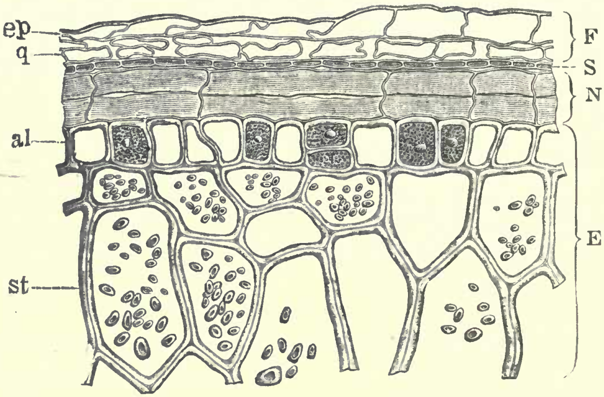


FIG. 100. Chess. Cross section of outer portion of fruit. *F* pericarp consists of *ep*, epicarp, and *q* cross cells; *S* spermoderm; *N* perisperm; *E* endosperm consists of *al* aleurone layer, and *st* starch parenchyma. ×160. (WINTON.)

conspicuously thick-walled, and the wavy-walled cells are throughout much longer than broad. The circular cells also have wavy walls. The cells on the margins, interspersed with lance-shaped hairs, are the same as in darnel.

Palet. The flowering glume and palet are similar in structure, but the outer epidermis of the latter is barbed on the keel, the stiff hairs often reaching 45 μ in length.

Pericarp (Fig. 100, *F*; Fig. 101). The pericarp consists of two layers with rudiments of another layer in parts.

1. *The Epicarp Cells* (*ep*) are large, elongated polygonal, and have thin, non-porous walls.

2. *Mesocarp.* As a rule, the cross cells immediately underlie the epidermis; but occasionally traces of the mesocarp are evident.

3. *Cross Cells* (*q*). Whether this layer corresponds with the cross cells or the tube cells of other grasses is uncertain. The tissue is made

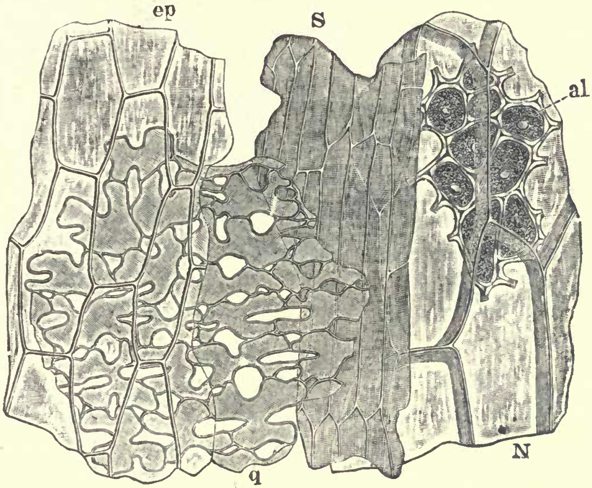


FIG. 101. Chess Bran coats in surface view. *ep* epicarp; *q* cross cells; *S* spermoderm; *N* perisperm; *al* aleurone cells. ×160. (WINTON.)

up of irregular spongy parenchyma cells, usually transversely elongated with large, round or elongated intercellular spaces.

The Spermoderm (*S*) consists of one layer of elongated brown cells 15–20 μ wide.

Perisperm (*N*). This layer is enormously developed. As may be seen in cross section, the cells are 40 μ thick, but the walls are so swollen as to almost entirely obliterate the cavity. After soaking for some time in 1¼ per cent soda solution they are evident in surface view.

Endosperm. 1. *The Aleurone Layer* (*al*) is not of especial interest.

2. *The Starch-Parenchyma* (Fig. 100, *st*) is remarkable for the thickness of the cell-walls (often 10 μ) and the elliptical starch grains 3–20 μ in diameter. With proper illumination each grain may be seen to have an elliptical hilum.

DIAGNOSIS.

Especially characteristic are the thick-walled parenchyma cells (Fig. 100, *st*) with elliptical starch grains. The cross cells (Fig. 101, *q*) also are of diagnostic importance. The epidermis (Fig. 99) of the flowering glume is distinguished from that of darnel by the bolder outlines of the wavy-walled cells and their greater length, as well as by the structure of the circular cells. The hairs on the keels of the palet are longer than those of darnel.

BIBLIOGRAPHY.

VOGL: Die wichtigsten vegetabilischen Nahrungs- u. Genussmittel. Berlin u. Wien, 1899, 36.

WINTON: Anatomie der Früchte des Taumellolches und der Roggentrespe. Ztschr. Unters. Nahr.-Genussm. 1904, 7, 321. Conn. Agr. Exp. Sta. 1903, 165.

BUCKWHEATS (*Polygonaceæ*).

Although buckwheat and other polygonaceous plants are botanically widely removed from the cereals, the fruits of the two families are quite similar in structure, as well as in chemical composition. In both, the pericarp is thin and dry, and the single seed consists of a thin spermoderm, a bulky endosperm with aleurone and starch cells, and a relatively small embryo. The following characters are peculiar to buckwheats: (1) the thin leaf-like or colored perianth, (2) the brown or black pericarp, without hairs, (3) the network of homogeneous threads remaining after dissolving the starch grains in alkali. The structure of the spermoderm taken as a whole is also characteristic, although some of the layers are quite like tissues found in the cereals.

The starch grains are of the rice type, but they do not occur in rounded aggregates.

COMMON BUCKWHEAT.

Nearly all the buckwheat raised in Europe and America as well as the larger part of that raised in oriental countries belongs to a single species (*Fagopyrum esculentum* Mœnch), a native of Central Asia. Tartary buckwheat (*F. Tartaricum* Gært.), a less valuable species, is described in the following chapter.

The sharply triangular, pointed, dark-brown or gray-brown achenes are 5–8 mm. long and 3–4 mm. broad. Fragments of the calyx are often attached to the base. A nerve passes longitudinally through the middle of each of the three sides. The seed completely fills the pericarp, but is not grown to it and is readily separated by machinery. On the other hand, the spermoderm adheres closely to the endosperm and is not entirely removed in milling. The embryo, with broad but thin cotyledons, is embedded in the endosperm, and is so folded that, in cross section, it is S-shaped.

HISTOLOGY.

Pericarp (Figs. 102 and 103). Sections are cut after soaking for some time in water. Surface preparations are obtained by scraping

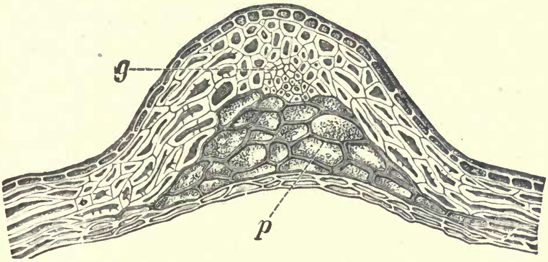


FIG. 102. Buckwheat (*Fagopyrum esculentum*). Cross section of the pericarp at one of the angles showing the epicarp, the hypoderm of sclerenchyma elements with fibro-vascular bundle (*g*), the brown parenchyma (*p*), and the inner layers of obliterated cells. ×160. (MOELLER.)

with a scalpel, after boiling for an hour in 1¼ per cent alkali to remove a portion of the brown coloring matter.

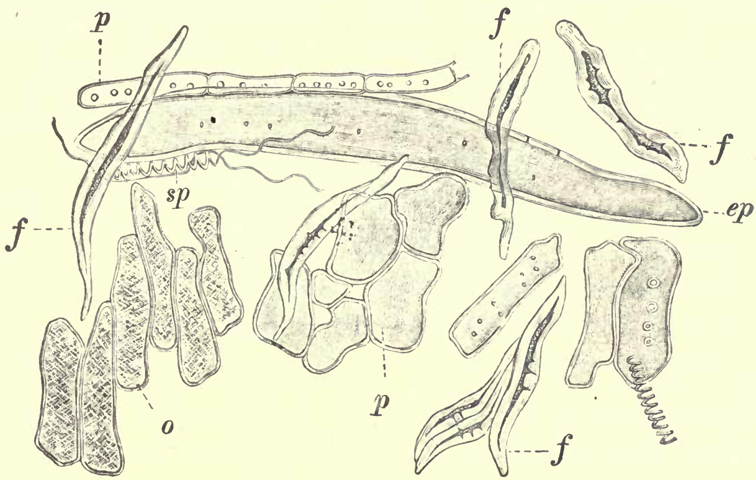


FIG. 103. Buckwheat. Isolated elements of the pericarp. *o* epicarp; *p* parenchyma (the upper group from a bundle); *f* hypoderm fibers; *ep* inner epidermis; *sp* spiral vessel. ×160. (MOELLER.)

1. *The Epicarp Cells* (*o*) are elongated, rounded quadrilateral and range up to 100 μ in length and 20 μ in breadth. Diagonally extended

pores on the outer wall, crossing those of the inner wall at nearly right angles, give the layer a peculiarly characteristic latticed appearance. Owing also to these pores the radial walls appear indistinctly beaded. On each of the three faces of the fruit the cells of both the epidermis and the hypoderm are pinnately arranged either side of the central vein, but on the angles of the fruit they are longitudinally extended.

2. *The Hypoderm* (*f*) consists of several layers of short fibers (up to 150 μ long, 10–15 μ broad), with thick porous walls. The narrow cavities contain a brown substance.

3. *Brown Parenchyma* (*p*). Only a single thin layer of parenchyma is present in the faces of the pericarp, but in the angles there are several layers. The cells are either isodiametric or elongated, with rather thick walls impregnated with a brown substance. This same substance is also found in the other layers, though in smaller amount. Through this tissue pass the bundles of the veins.

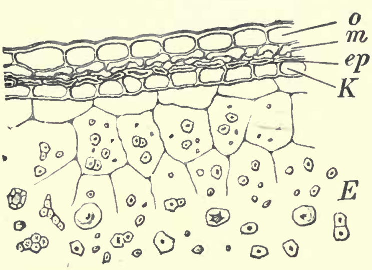


FIG. 104. Buckwheat. Cross section of outer portion of seed. Spermoderm consists of *o* outer epidermis, *m* spongy parenchyma, and *ep* inner epidermis; endosperm consists of *K* aleurone cells and *E* starch cells. ×160. (MOELLER.)

4. *An Endocarp* (*ep*), for the most part of large, elongated, mostly pointed cells, with somewhat thickened walls, covers the inner surface.

Spermoderm (Figs. 104 and 105). After the removal of the pericarp the seed is seen to be covered with a thin, yellowish membrane, which is best examined in cold dilute alkali. The three superimposed layers are easily found on careful focusing.

1. *Outer Epidermis* (*o*). Wavy-walled cells, isodiametric or somewhat elongated, form a conspicuous epidermal layer.

2. *Spongy Parenchyma* (*m*). Cells of various shapes, with numerous round intercellular spaces, underlie the epidermis, and with it form a most valuable means of identification. Greenish or brownish-yellow cell contents render this layer particularly distinct.

3. *An Inner Epidermis* (*ep*) of elongated, thin-walled cells, is readily found after the addition of cold dilute alkali.

Endosperm (Figs. 104 and 105). 1. *Aleurone Cells* (*K*) similar to those of the true cereals form an outer coat one cell layer thick. In cross section the cells are seen to be somewhat tangentially extended.

Surface mounts show that the cells are exceedingly variable both in size and wall thickness.

2. *Starch Parenchyma* (*E*). Cells of large size with thin walls contain the densely crowded, polygonal starch grains (Fig. 106). Isolated cells

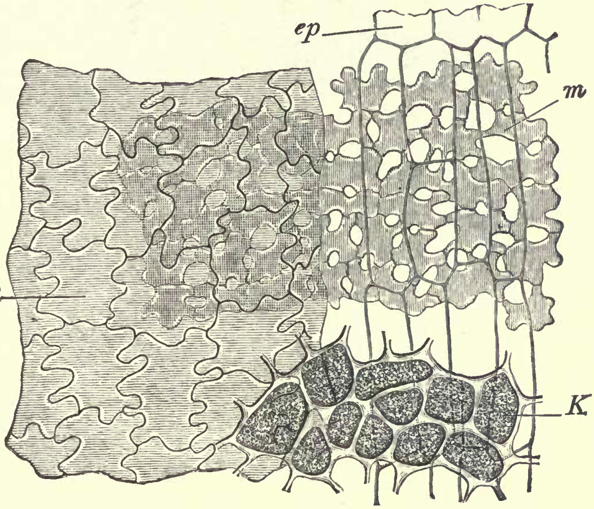


FIG. 105. Buckwheat. Bran coats in surface view. Spermoderm consists of *o* outer epidermis, *m* spongy parenchyma, and *ep* inner epidermis; *K* aleurone cells. ×300. (MOELLER.)

(Fig. 107) closely packed with grains are the most striking constituents of mill products. The starch grains range from less than 2 to over 15 μ

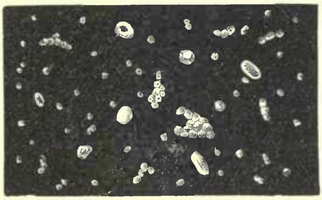


FIG. 106. Buckwheat Starch. ×300. (MOELLER.)

but are commonly 6–12 μ. They are either round or more commonly rounded polygonal and usually display a conspicuous hilum. Although the grains are never united into circular or elliptical aggregates, such as occur in rice, oats, and darnel, two or more of them are often joined to form a rod-like aggregate. As noted by Vogl these aggregates are often curiously constricted, and the contact surfaces of the individuals are indistinct.

Vogl also found that, on treating the starch masses with alkali, there was obtained a network of homogeneous threads (Fig. 108), not beaded

FIG. 107. Buckwheat. Starch grains in masses. ×110. (LEACH.)

as in *Setaria* and *Panicum*, corresponding to the outline of the dissolved grains. This phenomenon is also common to various species of *Polygonum* and *Rumex* and is probably characteristic of the entire family.

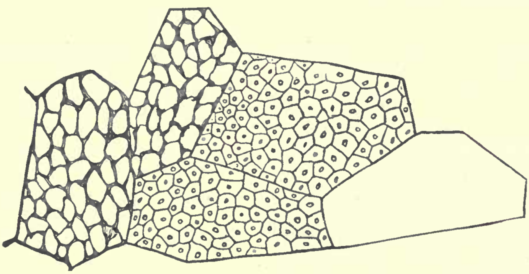


FIG. 108. Buckwheat. Starch cells of endosperm showing at the left network of homogeneous threads remaining after treatment with alkali. (VOGL.)

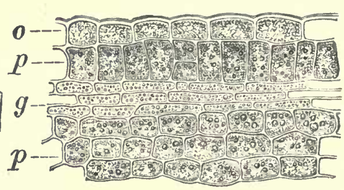


FIG. 109. Buckwheat. Longitudinal section of cotyledon. *o* epidermis; *p* mesophyl; *g* procambium or incipient bundle. (MOELLER.)

Embryo (Fig. 109). As appears in cross section, the two cotyledons consist of a mesophyl (*p*) between an outer and inner epidermis, and the elongated cells of the procambium (*g*) or incipient bundle running through the mesophyl.

The Mesophyl consists of small, polygonal cells with protoplasmic contents, the epidermis, of somewhat larger and more sharply defined cells of more or less elongated form.

DIAGNOSIS.

The whole grain is esteemed in Europe as a poultry food. It is seldom ground with the hulls.

Decorticated Products. *Buckwheat Flour* is employed, especially in America, for making griddle cakes. To the touch it has a peculiar harshness quite unlike the soft feeling of wheat and rye flour. It consists of parenchyma cells packed with starch grains (Fig. 107), isolated starch grains (Fig. 106), and occasional fragments of the spermoderm (Fig. 105).

The individual starch grains are much like those of oats, rice, and darnel, but they are never united into rounded aggregates. They are distinguished from *Setaria* and *Panicum* starch by the network of homogeneous threads left after treatment with alkali (Fig. 107). The rod-shaped and constricted aggregates are characteristic. Of greatest value in diagnosis are the fragments of the spermoderm (Fig. 105), consisting of the wavy-walled cells of the outer epidermis, the spongy parenchyma with greenish cell-contents and the elongated cells of the inner epidermis.

Buckwheat flour is often adulterated with cheaper flour. Of 107 samples examined in 1900 by the author, 26 contained wheat flour or wheat middlings, 9 maize flour, and 9 both wheat and maize flour.

Prepared or Self-raising Buckwheat Flour are names applied in America to griddle-cake preparations containing such proportions of salt and baking-powder that they may be prepared for cooking by simply mixing with water or milk. The flour in these preparations is either pure buckwheat flour or various mixtures of buckwheat, wheat, maize, rice, and barley flour. If, as is usually the case, the baking-powder used contains corn-starch as a filler, traces of this starch will be found under the microscope.

Buckwheat Grits is a valuable food for the common people in Russia and some oriental countries. It contains the same elements as the flour.

By-products. *Buckwheat Middlings*, a by-product from the manufacture of the flour, is readily identified by the tissues of the spermoderm (Fig. 105). It is used as a cattle food and also as an adulterant of spices.

Buckwheat Hulls have little food value, but make good packing. They have been extensively ground for adulterating black pepper. The latticed epicarp cells (Fig. 103, *o*) and the hypoderm fibers (*f*) are of chief value in identification.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Böhmer, (6, 23); Hanausek, T. F. (10, 16); Harz (18); Leach (25); Macé (26); Moeller (29); Planchon et Collin (34); Schimper (37); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (43, 45); Wittmack (10).

Also see Bibliography of Wheat, pp. 72 and 73.

HANAUSEK, T. F.: Reis- und Buchweizenstärke. Chem. Ztg. 1894, **18**, No. 33.

MEYER, ARTHUR: Arch. d. Pharm. 1883, 912.

TSCHIRCH: Stärkemehlanalysen. Archiv. d. Pharm. 1885, **23**, 521.

TARTARY BUCKWHEAT.

Indian wheat, Tartary buckwheat, or duckwheat (*Fagopyrum Tartaricum* Gærtn.) is known chiefly in the East. In Piedmont and some other cold, mountainous regions, it has been grown to some extent, as it ripens earlier than the common sort.

The grains are dull brown and have a marked longitudinal groove running through each of the three faces.

HISTOLOGY.

Pericarp. 1. *The Epicarp Cells* are isodiametric or somewhat elongated with thin, non-porous walls. On the inner surface they are convex, fitting into corresponding concave depressions of the next layer.

2. *Hypoderm.* In the outer two or more layers the fibers are transversely extended, but in the inner layer they are arranged longitudinally.

3. *The Brown Parenchyma* is much like that of common buckwheat.

4. *An Endocarp* of thin-walled cells completes the pericarp.

The Spermoderm, Endosperm, and Embryo are the same as in common buckwheat.

BLACK BINDWEED.

Of the several common weeds belonging to the genus *Polygonum*, black bindweed or wild buckwheat (*P. Convolvulus* L.) is the most troublesome. Although a native of the Old World, it thrives luxuriantly in the grain fields of the United States, and the seed is the chief impurity of American wheat. Samples of wheat screenings from the leading wheat-growing states of the Union contained from 8 to 27 per cent of this seed.

The jet black, lusterless, triangular achenes are 3 mm. long and the faces are 2 mm. broad (Fig. 110, *II*). Since the achenes at maturity are closely invested by the calyx (*I*), both are harvested together; but during threshing, screening, and transportation, the dry calyx, as a rule, is removed

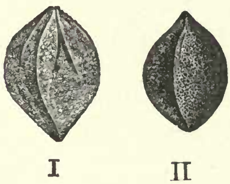


FIG. 110. Black Bindweed (*Polygonum Convolvulus*). *I* Fruit with calyx. *II* Fruit without calyx. ×5. (WINTON.)

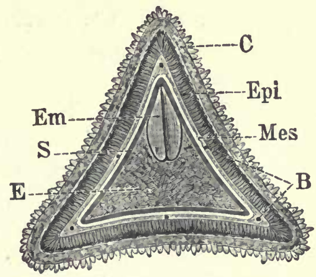


FIG. 111. Black Bindweed. Cross section of fruit. *C* calyx; *Epi* epicarp; *Mes* mesocarp; *B* fibro-vascular bundle; *S* spermoderm; *E* endosperm; *Em* embryo. ×16. (WINTON.)

from the achenes, and the pericarp, splitting at the angles, is often separated from the seed.

The seed consists of a thin, colorless spermoderm, a starchy endosperm, and a minute embryo situated in a longitudinal groove of the endosperm at one of the angles.

HISTOLOGY.

Calyx (Figs. 111 and 112, *C*). The three outer lobes of the five- to six-lobed calyx are broader than the others and are slightly keeled at the angles.

1. *Outer Epidermis* (Fig. 112, *aep*). Distributed over the outer surface are numerous characteristic blunt-conical or nipple-shaped papillæ from 30–60 μ in diameter at the base, each of which is marked with longitudinal striations. These papillæ, as may be seen in transverse section, are the outer portions of the epidermal cells, the inner portions forming a continuous cell layer.

2. *Mesophyl* (*m*). Between the outer and inner epidermis are several layers of chlorophyl-containing parenchyma with intercellular spaces.

3. *Inner Epidermis* (*iep*). Elongated cells with more or less wavy outline and varying in length up to 200 μ and in breadth from 15–45 μ, interspersed here and there with stomata, make up the inner coat of the calyx.

Pericarp (Figs. 113–115). The black hulls or shells of the grain should be studied in cross section and in surface preparations, the latter being freed from the black coloring matter by warming on the slide with caustic alkali, or better by boiling for half an hour with $1\frac{1}{4}$ per cent sodium hydrate solution as in the determination of crude fiber.

1. *Epicarp* (*epi*). Cross sections show that the cells are about 100 μ in radial diameter on the sides of the achenes and are still longer at the

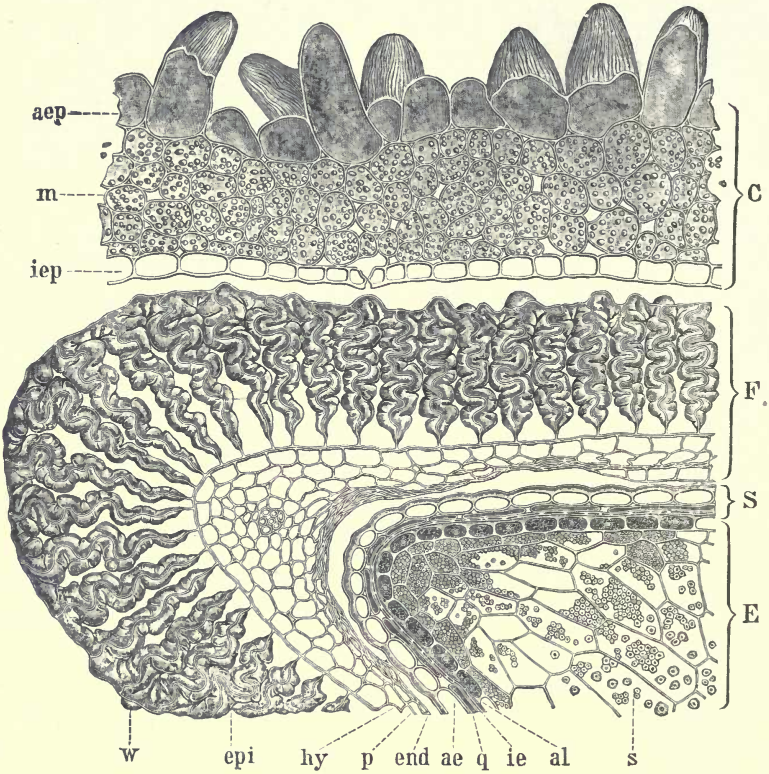


FIG. 112. Black Bindweed. Cross section of calyx and angle of fruit. *C* calyx consists of *aep* outer epidermis, *m* mesophyl, and *iep* inner epidermis; *F* pericarp consists of *epi* epicarp with *w* cuticular wart, *p* mesocarp, and *end* endocarp; *S* spermoderm consists of *ae* outer epidermis, *q* cross cells, and *ie* inner epidermis; *E* endosperm consists of *al* aleurone cells and *s* starch cells. ×160. (WINTON.)

angles. The inner wall is thin, but the outer wall and the outer portions of the curiously wrinkled radial walls are strongly thickened. Proceeding from the inner wall outward, the radial walls increase in thickness until the much-branched cell cavity is almost obliterated. On the surface are numerous warts from 15–30 μ in diameter, into each of which a narrow branch of the cell cavity passes.

Surface preparations of the pericarp with the outer surface uppermost clearly show that the warts are arranged in irregular longitudinal rows, also that the epicarp cells at the surface are sinuous in outline

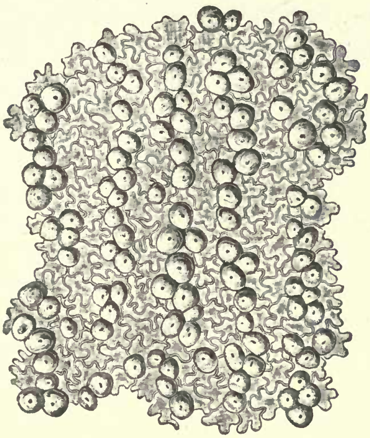


FIG. 113. Black Bindweed. Epicarp in surface view showing wavy outline of cells and cuticular warts. ×160. (WINTON.)

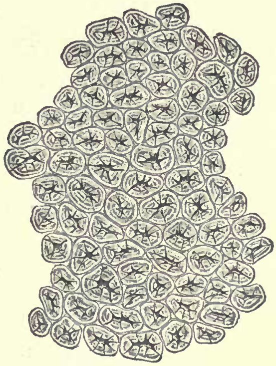


FIG. 114. Black Bindweed. Tangential section of epicarp. ×160. (WINTON.)

(Fig. 113), but further inward gradually approach a circular form (Fig. 114).

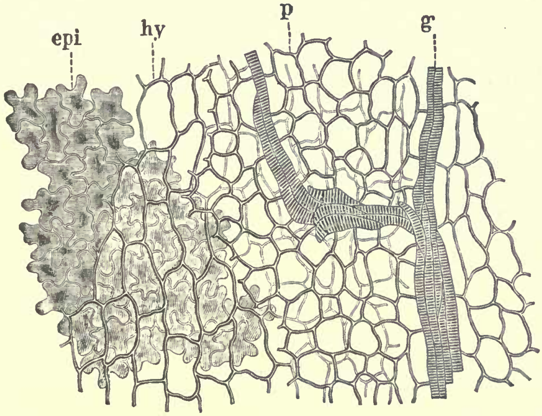


FIG. 115. Black Bindweed. Surface view of pericarp from below. *epi* epicarp; *hy* hypoderm; *p* mesocarp with *g* bundle. ×160. (WINTON.)

As may be seen in preparations of the pericarp with the inner surface uppermost, the contour of the inner cell-walls of the epicarp is, like the outer wall, sinuous in outline (Fig. 115, *epi*).

2. *Hypoderm* (Figs. 112 and 115, *hy*). Beneath the epicarp is a layer of slightly elongated parenchyma cells somewhat larger than the cells of the mesocarp.

3. *Mesocarp* (*p*). At the angles of the fruit this layer is somewhat thicker than on the sides. The cells of the ground tissue are thin-walled and isodiametric, those of the inner layers being more or less obliterated in the ripe fruit. Six primary, sparingly branched vascular bundles pass longitudinally through the ground tissue of the mesocarp, one in each angle and one in each of the faces.

4. *Endocarp* (Fig. 112, *end*). Like the inner mesocarp, the cells are usually obliterated in the mature seed and are seldom evident either in cross section or in surface view.

Spermoderm (Fig. 112, *S*; Fig. 116). Three coats, analogous to those of buckwheat, but differing in form, make up the spermoderm.

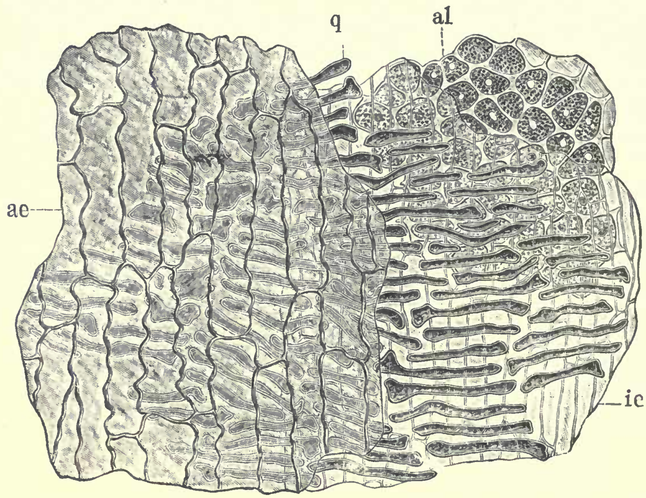


FIG. 116. Black Bindweed. Seed in surface view. *ae* outer epidermis, *q* cross cells, and *ie* inner epidermis of spermoderm; *al* aleurone cells. ×160. (WINTON.)

1. *Epidermis* (*ae*). As in buckwheat, the epidermal cells are wavy in outline; but they are strongly elongated, whereas in buckwheat they are nearly isodiametric.

2. *Cross Cells* (*q*). Most of the cells of this layer are elongated, resembling the tube cells of cereals; but short cells of more irregular shape also occur, particularly near the base and apex. In no part do they form a spongy parenchyma with circular intercellular spaces like that of buckwheat.

3. *Inner Epidermis* (*ie*). The coat consists of thin-walled, elongated elements.

Endosperm (Figs. 111 and 112, *E*). None of the elements are distinguishable from those of buckwheat, either in form or size.

1. *Aleurone Cells* (Figs. 112 and 116, *al*) are of variable size and irregular shape.

2. *Starch Cells* (Fig. 112, *s*). In the outer layers the cells are tangentially elongated; further inward, they are radially elongated and of large size. The polygonal or rounded grains vary in diameter from 3–12 μ.

As in buckwheat and other species of *Polygonum* and *Rumex*, a network of homogeneous threads, corresponding to the outline of the starch grains, remains behind after dissolving out the starch in alkali.

The Embryo, consisting of an elongated radicle and two oblong cotyledons, may be conveniently isolated by soaking the seed in $1\frac{1}{4}$ per cent caustic soda solution for some hours until the starch is removed.

DIAGNOSIS.

Ground screenings containing a large percentage of this seed has been sold in the United States as a fodder ("Germ Middlings," etc.), and has been used as an adulterant of ground pepper. Fragments of the seed, particularly the black hulls, are frequently encountered as an accidental impurity in bran and other by-products.

Characteristic of this fruit are the papillæ on the outer epidermis (Fig. 112, *aep*) of the calyx, also the epicarp (Fig. 113) with sinuous cell-walls and rows of warts.

The outer epidermal cells (Fig. 116, *ae*) of the spermoderm are sinuous in outline, like those of buckwheat, but are commonly more elongated.

Although the cross cells (*q*) are morphologically the same as the spongy parenchyma of buckwheat, they resemble more nearly in structure the tube cells of the cereals.

The starch grains, also the network of homogeneous threads obtained after treatment with alkali, are characteristic of the family, not of the species.

BIBLIOGRAPHY.

KRAUS: Pringsh. Jahrb. f. wissensch. Bot. 1866, 5, 83.
VILLIERS ET COLLIN: Traité des Altérations et Falsifications. Paris, 1900, 103.
WINTON: Ueber amerikanische Weizen-Ausreuter. Ztschr. Unters. Nahr.-Genussm. 1903, 6, 433. Conn. Agr. Exp. Sta. Rep. 1902, 339.

OTHER POLYGONACEOUS SEEDS.

A number of European and American species of *Polygonum* and *Rumex* are troublesome weeds.

The black or brown seeds are either triangular or flattened, rough or more commonly lustrous.

The anatomical structure of most of them resembles that of black bindweed. The epicarp cells in surface view are commonly sinuous with or without cuticular warts; the starch grains polygonal, of the buckwheat type.

WEED SEEDS.

Of the weeds which infest grain fields, some are so low-growing that they escape cutting with the grain, others ripen their seed before or after the grain is harvested, and others still, including some of the rankest weeds, have such small seeds that they do not appreciably add to the weight of the grain. Of the seeds harvested with the grain by far the larger part, being larger or smaller than the grain, are separated as screenings, so that the cleaned grain is nearly, although never quite, free of foreign seeds.

European Screenings. According to Vogl the commonest weed seeds of European grain are *Agrostemma Githago* L. (cockle) and legumes, although the following occur in considerable quantities: *Vaccaria parviflora* Moench (cow herb); Species of *Galium* (bed straws); *Bifora radians* M. B.; *Bromus secalinus* L. (chess); *Lolium temulentum* L. (darnel); *Avena fatua* L. (wild oats); *Centaurea Cyanus* L. (corn flower); *Papaver Rhoeas* L. (corn poppy); *Lithospermum arvense* L.; Species of *Atriplex; Convolvulus arvensis* L. (small bindweed); Species of *Polygonum*, especially *P. Convolvulus* L. (black bindweed); *Melampyrum arvense* L. (cow wheat); *Alectorolophus hirsutus* Allion; *Delphinium Consolida* L. (larkspur); *Ranunculus arvensis* L. (buttercup); etc. Fruits of species *Setaria* (foxtail) and some umbelliferous plants, seeds of cruciferous plants, etc., occur only in small amounts.

In a sample of wheat screenings from one of the largest steam mills near Vienna, Vogl found: broken wheat 41.7 per cent, cockle 42.7 per cent, legumes 6.4 per cent, bed straws 3.3 per cent, *Atriplex* 3.1 per cent, *Polygonum* species 1.1 per cent, miscellaneous 0.6 per cent; while in another sample he found broken wheat, etc., 42.1 per cent, cockle 29.7 per cent, legumes 11.1 per cent, *Bifora radians* 4.9 per cent, bed straws 3.5 per cent, *Polygonum* species 2.0 per cent, cow wheat 2.5 per cent, cruciferous species 1.4 per cent, miscellaneous 2.3 per cent.

A sample of so-called "tares" consisted chiefly of legumes with small amounts of broken wheat, cockle, etc. One known as "chicken or small wheat" consisted largely of small wheat kernels mixed with chess (4.3 per cent) and other fruits and seeds, including three kernels of foxtail.

The foreign matter in a sample of uncleaned wheat was chess, cockle and small amounts of other impurities, including two fruits of black bindweed.

American Screenings. The chief wheat-growing regions of America may be divided into three sections: First, the spring wheat section of the middle west, including Kansas, Ohio, Indiana, Missouri, Illinois, southern Nebraska, southern Michigan, and the adjoining states to the south; second, the winter wheat section of the middle northwest, including the states of Minnesota, North Dakota, South Dakota, Iowa, Wisconsin, northern Nebraska, and Canada; third, the Pacific section, including the states of California, Oregon, and Washington.

Botanical analyses of screenings from the first two of these sections are given on p. 147.

From these it appears that the screenings of the Old and New World are quite different at the present time. Of the two chief constituents of European screenings, cockle occurs in small amount and leguminous seeds not at all in the American product, while the three leading seeds of American screenings (black bindweed, green foxtail, and yellow foxtail), although introduced from Europe, are of minor importance in their native land. Chess is often met with in considerable amount on both continents.

No analyses of screenings from the Pacific coast are available, but it is well known that the product differs markedly in constitution from that of the East.

Hilgard[1] in 1890 stated that in California all of the species of Polygonum excepting *P. aviculare* were almost unknown, and chess, although found here and there, had failed to gain a foothold as a weed.

Darnel (*Lolium temulentum* L.) and wild oats (*Avena fatua* L.) were named, however, as serious pests in the California wheat fields.

Uses of Screenings. The seeds of charlock are separated in large quantities from the screenings of the spring wheat section of the United States, and are used as a substitute for true mustard. It is probable that some of the samples described in the table on p. 147 represent the residue after this separation.

Screenings are particularly adapted for poultry food, as poultry pick

[1] California Agricultural Experiment Station Report, 1890, p. 238.

BOTANICAL ANALYSES OF AMERICAN WHEAT SCREENINGS.

Name of Seed, Fruit or Impurity.	Spring Wheat Screenings.			Winter Wheat Screenings.		Wheat Screenings Bought in Connecticut. Further particulars unknown.					
	From Mill in New York City.	From Mill in Milwaukee.	Average of Five Largest Mills in Minneapolis.	From Mill in Detroit.	From Mill in Alton, Ill.[1]						
	%	%	%	%	%	%	%	%	%	%	%
Broken and shrivelled Wheat	48.2	67.5	19.8	69.6	38.8	49.3	41.4	44.9	40.0	69.5	42.0
Straw and Chaff	11.4	3.2	24.2	4.2	10.0	5.2	13.0	10.0	6.5	3.7	5.5
Dust (material finer than 1 mm.)	3.8	0.2	17.4	1.0	0.6	2.0	4.2	3.8	3.7	1.3	5.8
Black Bindweed (*Polygonum Convolvulus* L.)	18.0	15.8	12.8	9.4	0.1	17.8	27.0	24.5	23.6	8.9	23.1
Green Foxtail (*Setaria viridis* Beauv.)	2.2	1.2	7.4	0.8	0.0	11.6	3.0	4.2	10.9	5.9	10.0
Yellow Foxtail (*Setaria glauca* Beauv.)	5.6	8.1	5.4	0.8	0.0	1.8	0.7	1.0	3.0	1.9	2.9
Chess (*Bromus secalinus* L.)	0.0	0.0	0.0	6.6	49.3	2.8	trace	trace	0.0	2.2	trace
Flax (*Linum usitatissimum* L.)	3.4	0.4	2.0	3.1	0.0	3.8	3.7	4.9	4.9	0.7	4.0
Oats (*Avena sativa* L.)	3.6	2.0	3.2	2.1	trace	1.9	3.9	3.7	3.9	2.7	3.6
Ragweed (*Ambrosia artemisiæfolia* L.)	0.6	0.0	0.0	0.6	0.0	0.4	1.2	1.0	1.2	0.3	0.8
Wild Mustard (*Brassica sinapistrum* Bois.)	0.0	1.2	2.8	0.2	0.0	0.6	0.3	0.5	0.5	1.1	0.6
Cockle (*Agrostemma Githago* L.)	0.0	0.0	0.0	0.4	0.0	0.5	0.0	0.0	0.0	0.5	0.0
Pigweed, etc. (*Amaranthus* and *Chenopodium* species)	0.0	0.0	2.0	trace	0.0	1.0	0.6	0.6	0.9	0.3	0.8
Miscellaneous Seeds	3.2	0.4	3.0	1.2	1.2	1.3	1.0	0.9	0.9	1.0	0.9
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[1] This sample represents only the coarser materials separated from the grain and does not include the dust, smaller, seeds, etc.

out the valuable seeds one by one, avoiding any that are distasteful. They are also used for feeding sheep, swine, and other farm animals. In Chicago, New York, and some other grain centers, ordinary screenings are separated into two products, one consisting largely of broken and shrunken wheat, the other of weed seeds, notably black bindweed, green foxtail and yellow foxtail. The weed seeds are made into proprietary cattle foods sold under such names as "germ middlings," "seed meal," etc., and are used also as adulterants.

Examination of Screenings and Products of Screenings.

Samples of unground screenings may be separated into their constituents by sifting and careful sorting. The individual seeds are best identified with the aid of a standard collection (see p. 11).

Microscopic examination coupled with determinations of the proximate constituents is sufficient for the identification of mill products of screenings, and also for the detection of weed seeds in various cereal products, spices, etc.

Seeds of graminaceous and polygonaceous weeds are described with the cereals (pp. 118–132) and buckwheats (pp. 138–144). The following belong to other families.

CARYOPHYLLACEOUS SEEDS

(*Caryophyllaceæ*).

COCKLE.

One of the chief impurities in European grain is the seed of cockle (*Agrostemma Githago* L.). This seed is also found in American wheat, but in smaller amount than the fruit of black bindweed, green foxtail, and yellow foxtail.

The black or dark-brown campylotropous seeds are globular-kidney-shaped, resembling a rolled-up caterpillar (Fig. 117). Rows of stout warts arranged in semicircular lines about the hilum are evident even to the naked eye and especially to the sense of touch. The long, yellow-green embryo forms a ring about the pure white, mealy endosperm.

Cockle is an especially undesirable impurity in grain, as it contains a poisonous principle known as "sapotoxin."

HISTOLOGY.

Spermoderm. 1. *Outer Epidermis* (Fig. 118, *o*; Fig. 119). Highly characteristic of cockle are the large, more or less elongated (up to 600 μ

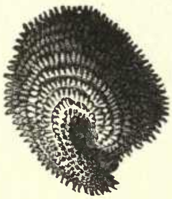


FIG. 117. Cockle (*Agrostemma Githago*). Natural size and enlarged. (NOBBE.)

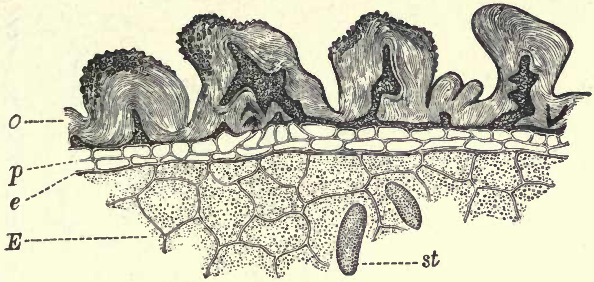


FIG. 118. Cockle. Cross section of outer portion of seed. Spermoderm consists of *o* outer epidermis, *p* parenchyma, and *e* inner epidermis; *E* endosperm consists of thin-walled cells containing *st* starch aggregates. ×160. (MOELLER.)

long) epidermal cells, with enormously thickened, deeply sinuous, brown walls. These cells form humps, covered on the outer surface with numer-

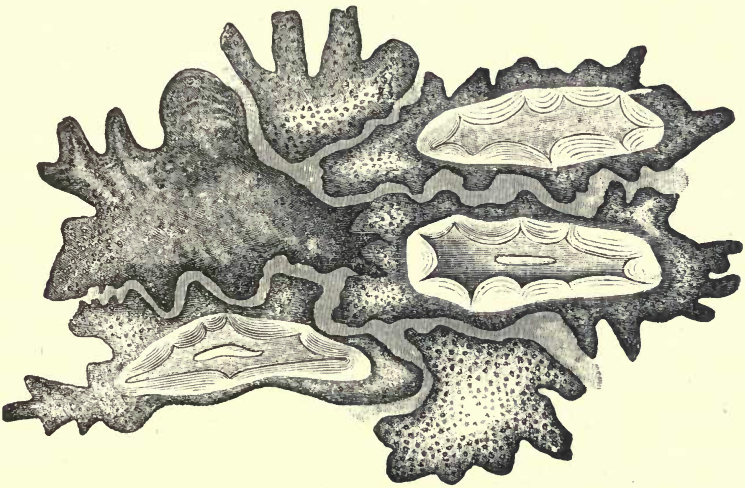


FIG. 119. Cockle. Outer epidermis of spermoderm in surface view. ×160. (MOELLER.)

ous fine warts. They contain a brown substance which is not removed by dilute alkali even on boiling.

2. *Parenchyma* (Figs. 118 and 120, *p*). Beneath the epidermis are one or more layers of parenchyma cells with somewhat thickened, brown

walls. These, like the cells of the epidermis, are more or less transversely elongated.

3. *Reticulated Cells* (*e*). A layer of colorless, isodiametric polygonal cells with delicate reticulations adjoins the endosperm. Some authors

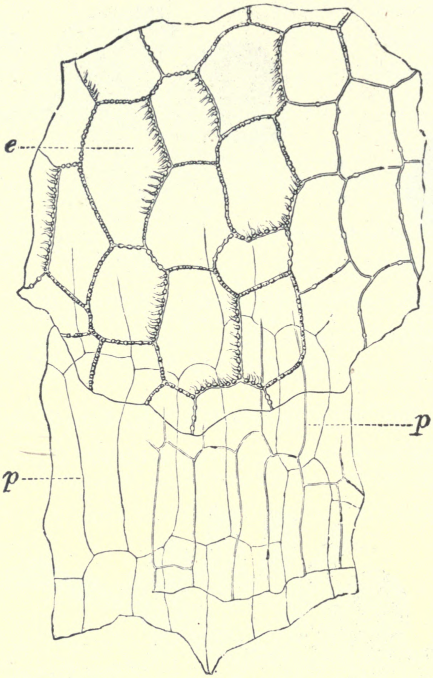


FIG. 120. Cockle. Inner layers of spermoderm in surface view. *p* parenchyma; *e* inner epidermis. ×160. (MOELLER.)

describe this layer as the inner epidermis of the spermoderm; Vogl, however, regards it as perisperm.

Endosperm (Fig. 118, *E*). The large cells contain highly characteristic, oval-fusiform, club-shaped, or, less often, globular bodies 20–100 μ in diameter, composed of minute (scarcely measurable) starch grains. These starch bodies slowly disintegrate in cold water, the liberated grains displaying lively molecular movements.

The Embryo contains aleurone grains of considerable size.

DIAGNOSIS.

The epidermal layer often occurs as pieces of considerable size in bran and similar coarse products. If examined under a lens or held with a needle and scraped with a scalpel, the rough surface (Fig. 117) is very evident. Under the microscope, a glance suffices for the identification of this remarkable tissue (Fig. 119). The coloring matter is little acted on by alkali. Equally striking are the starch masses (Fig. 118, *st*) of the endosperm.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Böhmer (6, 10, 23); Hanausek, T. F. (16); Harz (18); Macé (26); Moeller (29); Schimper (37); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (45); Wittmack (10).

BENECKE: Ueber den Nachweis des Samens der Kornrade (*Agrostemma Githago* L.) in Mahlprodukten. Landw. Vers.-Stat. **31**, 407.

KRUSKAL: Ueber *Agrostemma Githago*. Arb. d. pharmakol. Inst. Dorpat. 1891, **6**, 116.

LEHMANN: Arch. Hyg. 1893, **19**, 104.

MEYER, A.: Mikroskopischer Nachweis von Radenmehl in Getreidemehlen. Hannoversche Monatsschrift "Wider die Nahrungsfälscher," 1880, Heft X.

PETERMANN: Sur la presence des graines de *Lychnis Githago* (nielle) dans les farines. Ann. chim. phys. 1880, **19**, 243.

COW HERB.

The globular seeds of *Vaccaria parviflora* Moench (*Saponaria Vaccaria* L.) are a common impurity of European wheat.

In general structure they resemble cockle, but are distinguished by the more uniform height of the epidermal cells (Fig. 121) and especially by the absence of papillæ on these cells.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Villiers et Collin (42); Vogl (45).

SOAPWORT.

Soapwort, or bouncing bet (*Saponaria officinalis* L.), a common roadside weed with a handsome flower, has a roughened, dark brown seed smaller than cockle (1–1.5 mm.), but closely resembling it in other respects.

The wavy epidermal cells are not warty.

BIBLIOGRAPHY.

HARZ: Samenkunde, p. 1081.

SPURREY.

The seeds of common spurrey (*Spergula arvensis* L.) often occur in linseed-cake and other concentrated feeds.

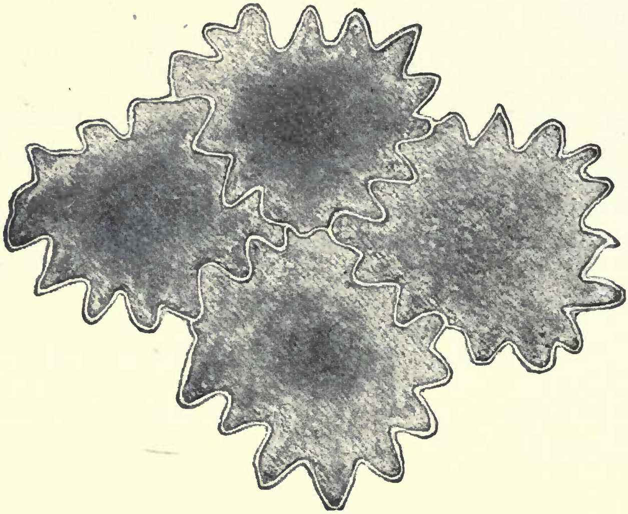


FIG. 121. Cow Herb (*Vaccaria parviflora*). Outer epidermis of spermoderm in surface view. (MOELLER.)

They are 1–1.5 mm. broad, circular in outline, and slightly flattened. The seed itself is dark brown, but is encircled by a narrow wing of a straw color.

FIG. 122. Spurrey (*Spergula arvensis*). Seeds natural size and enlarged. (NOBBE.)

This seed is readily identified under the microscope by the curious club-shaped, warty bodies on the outer surface, which are but modified epidermal cells (Fig. 123). The other epidermal cells are sinuous in outline like those of cockle and many other seeds of the same family (Fig. 124).

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Böhmer (23); Harz (18).

RANUNCULACEOUS SEEDS
(*Ranunculaceæ*).

This family includes a number of weeds, the seeds of which are particularly objectionable ingredients of grain because of their poisonous constituents.

Nearly all the representatives of the family have flowers with several or many pistils ripening either into single-seeded achenes or several-seeded pods.

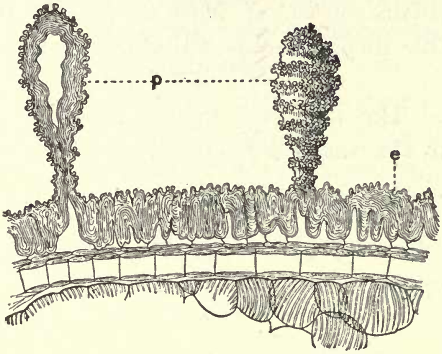


FIG. 123. Spurrey. Cross section of seed showing *e* outer epidermis of spermoderm with *p* outgrowths from the centers of the cells. (COLLIN and PERROT.)

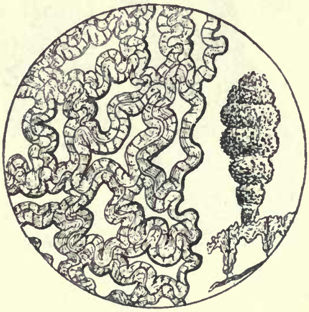


FIG. 124. Spurrey. Epidermis of spermoderm in surface view. (COLLIN and PERROT.)

The brief descriptions which follow are based on Senft's valuable paper, to which the reader is referred for further details.

BIBLIOGRAPHY.

SENFT: Die Bestandtheile des Ausreuters aus der Familie der Ranunculaceen. Pharm. Praxis. 1902, **1**, 65.

BUTTERCUP FRUIT.

Of the several species of *Ranunculus* infesting cultivated fields, the fruit of only one (*R. arvensis* L.) is here described, although those of the other species are very similar in microscopic structure.

The achenes (Fig. 125) are 5–6 mm. long, 1 mm. thick, keeled, and have a blunt beak and tapering base. On the flattened inner side they are prickly.

Fruits of other species are shown in Fig. 126.

HISTOLOGY.

The Pericarp consists of four layers: (1) The epicarp of yellow-brown cells extended into papillæ; (2) parenchyma forming a single layer of tangentially elongated cells of a yellow-brown color; (3) crystal cells (100 μ) with dark-brown walls; (4) sclerenchyma fibers for the most part longitudinally extended in the outer, transversely in the inner layers.

Spermoderm. (1) The outer layer has detached, rounded, transversely elongated, thick-walled cells; (2) the inner layer, longitudinally elongated, closely united cells with porous walls.


FIG. 125. Field Buttercup (*Ranunculus arvensis*). Seed, natural size and enlarged. (NOBBE.)

Perisperm. This consists of more or less quadrilateral cells with thick, porous walls and granular contents.

Endosperm. The cells are thick walled (up to 9 μ) and contain aleurone grains embedded in fat.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Harz (18); Villiers et Collin (42). Also see Senft, *loc. cit.*

ADONIS FRUIT.

The compound fruits of *Adonis aestivalis* L. and *A. Flammea* L. consist of numerous one-seeded, beaked achenes.

The Pericarp tissues are: (1) an epicarp made up of polygonal cells with striated cuticle and stomata; (2) a parenchyma tissue of several obliterated layers containing small oxalate crystal clusters; (3) an outer endocarp of several layers of large, strongly thickened sclerenchyma cells, many of which contain crystals; and (4) an inner layer of transversely elongated fibers.

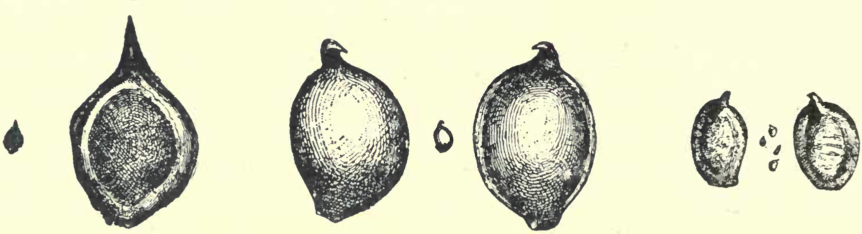


FIG. 126. Buttercup Seeds. *I, Ranunculus repens; II, R. acris; III, R. sceleratus.* Natural size and enlarged. (NOBBE.)

Spermoderm. Of the three layers, the middle layer, with porous, distinctly striated, yellow walls, is alone worthy of mention.

The Endosperm contains aleurone grains up to 14 μ long.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Harz (18); Villiers et Collin (42). Also see Senft, *loc. cit.*

LARKSPUR SEED.

The characteristic tissues of the field larkspur (*Delphinium Consolida* L.) are the outer epidermis and third layer of the spermoderm.

The outer epidermal cells have strongly thickened outer walls with minute warts. Curious fan-like outgrowths of this layer are highly characteristic. The third layer is of longitudinally elongated, narrow, reticulated cells.

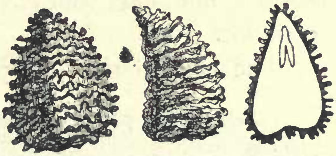


FIG. 127. Field Larkspur (*Delphinium Consolida*). Seed, natural size and enlarged; also longitudinal section showing the embryo. (NOBBE.)

The macroscopic characters are shown in Fig. 127.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Harz (18); Planchon et Collin (34); Villiers et Collin (42); Vogl (44). Also see Senft, *loc. cit.*

LOUSE SEED.

In this species (*Delphinium Staphysagria* L.) the brown walls of the epidermis of the spermoderm are strongly thickened throughout,

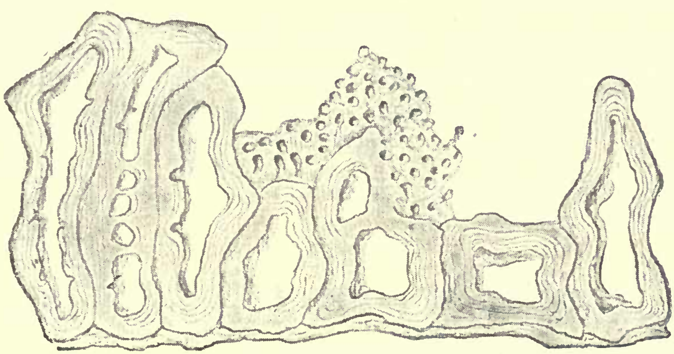


FIG. 128. Louse seed (*Delphinium Staphysagria*). Outer epidermis of spermoderm in cross section. (MOELLER.)

and are marked by beautifully distinct concentric rings. The outgrowths on the cuticle are here finger-shaped, up to 9 μ broad and 30 μ long (Fig. 128).

BLACK CARAWAY.

The seeds of *Nigella arvensis* L. are irregularly triangular, flattened, about 2 mm. long and 1.2 mm. broad. On the surface they are finely granular.

The characteristic elements as seen in surface view are the large

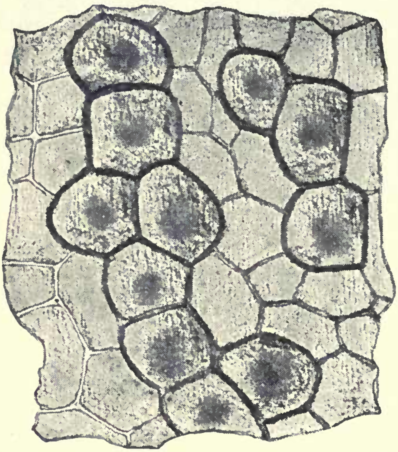


FIG. 129. Black Caraway (*Nigella arvensis*). Outer epidermis of spermoderm in surface view. (MOELLER.)

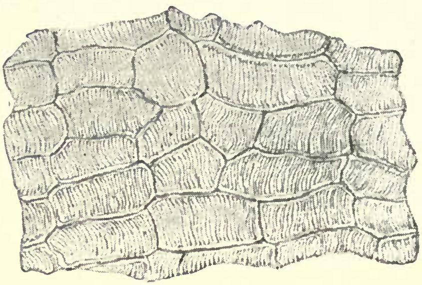


FIG. 130. Black Caraway. Spiral cells of spermoderm in surface view. (MOELLER.)

(100 μ broad) papillæ-like, dark-brown epidermal cells (Fig. 129) and the 4–5 sided striated, cross-cells of the third layer (Fig. 130).

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Harz (18); Planchon et Collin (34); Vogl (44). Also see Senft, *loc. cit.*

MISCELLANEOUS WEED SEEDS.

COW-WHEAT.

In many regions cow-wheat (*Melampyrum arvense* L. order *Scrophulariaceæ*) is an abundant weed, and its seed finds its way into grain. The brown, oval seed (Fig. 131) is somewhat smaller than wheat and contains a horny endosperm, in the axis of which is embedded the minute embryo.

Only traces of the spermoderm are present, the bulk of the seed consisting of thick-walled endosperm (Figs. 132 and 133). The cells in the outer layer are radially elongated, elsewhere isodiametric, usually about

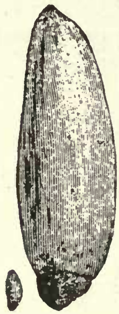


FIG. 131. Cow Wheat (*Melampyrum arvense*). Seed, natural size and enlarged. (NOBBE.)

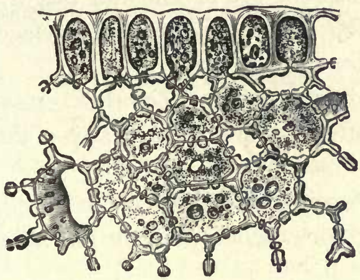


FIG. 132. Cow Wheat. Cross section of spermoderm (obliterated cells) and endosperm. ×160. (MOELLER.)

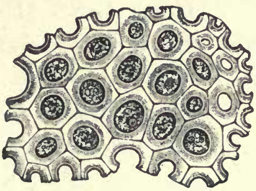


FIG. 133. Cow Wheat. Outer layer of endosperm in surface view. ×160. (MOELLER.)

50 μ in diameter. The double walls are 15 μ thick, and, excepting the outer and radial walls of the outer layer, are pierced by distinct pores.

Oil globules and finely granular protoplasm are the only visible contents.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Böhmer (6, 23); Hanausek, T. F. (16); Macé (26); Moeller (29); Schimper (37); Vogl (43, 45); Wittmack (10).

TSCHIRCH: Entwicklungsgeschichtliche Studien. Schw. Woch. Chem. Pharm. 1897, 35, No. 17.

BINDWEED.

In some regions the wild morning glory or field bindweed (*Convolvulus arvensis* L. order *Convolvulaceæ*) is a serious pest in grain fields, the vines twining on the grain stalks, thus checking their growth and the seeds finding their way into the threshed grain.

The black seed is the shape of an orange segment, about 4 mm. long and 2.5 mm. broad (Fig. 134). It consists of a shell-like spermoderm, a bulky endosperm, and an embryo with curiously folded cotyledons.

HISTOLOGY.

Spermoderm. Cross-sections and surface mounts, the latter prepared after boiling the seed in 1¼ per cent alkali, serve for the study of the seed coats.

1. *Outer Epidermis.* The cells are of unequal height, the outer walls often being convex, forming short papillæ. In surface view they are polygonal and show dark-brown contents.

2. *Cross Cells.* Exceedingly narrow, colorless cross cells arranged side by side in rows and often parqueted make up a thin subepidermal layer.

3. *The Palisade Cells* forming the third layer are about 75 μ high, and are of a yellow-brown color except for a light line about 15 μ from the outer end. The narrow lumen broadens somewhat near the light line. These cells resemble the palisade cells of cottonseed.

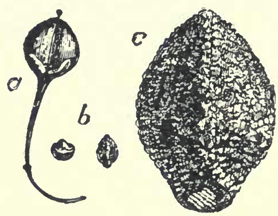


FIG. 134. Bindweed (*Convolvulus arvensis*). *a* fruit; *b* seed, natural size; *c* seed, enlarged. (NOBBE.)

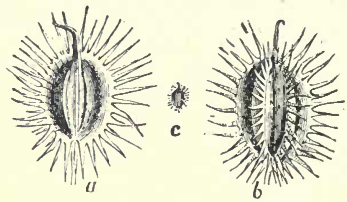


FIG. 135. Wild Carrot (*Daucus Carota*). *a* fruit showing inner or commissural surface, enlarged; *b* showing outer surface, enlarged; *c* fruit, natural size. (NOBBE.)

4. *Parenchyma Cells* form the inner layers of the spermoderm.

Endosperm. The cells have very thick, more or less mucilaginous walls.

DIAGNOSIS.

The epidermal cells with brown contents, the narrow cross cells, and the palisade cells serve for the identification of this seed in powder form.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Harz (18); Villiers et Collin (42).

WILD CARROT.

The fruit of the wild form of *Daucus Carota* L. (order *Umbelliferæ*) is broadly ovoid, 1.5–2.5 mm. long (Fig. 135). The secondary ribs are barbed with bristles over 1 mm. long, while the inconspicuous main ribs are sparingly hairy. The bristles are made up of numerous axially arranged, narrow, elongated cells. Oil ducts are present only in the secondary ribs.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Harz (18).

HOLLOW SEED.

According to Vogl, *Bifora radians* M. B. (order *Umbelliferæ*) is an abundant weed in Austrian grain fields, particularly in the region south of Vienna, and the fruit frequently occurs in considerable amount in screenings. In one sample of screenings he found 4.9 per cent of this fruit.

The pericarp lacks conspicuous ribs and has no oil ducts whatever.

HISTOLOGY.

Pericarp (Fig. 136) 1. *The Epicarp* (*I*, *Ep*) is smooth, without distinctive characters.

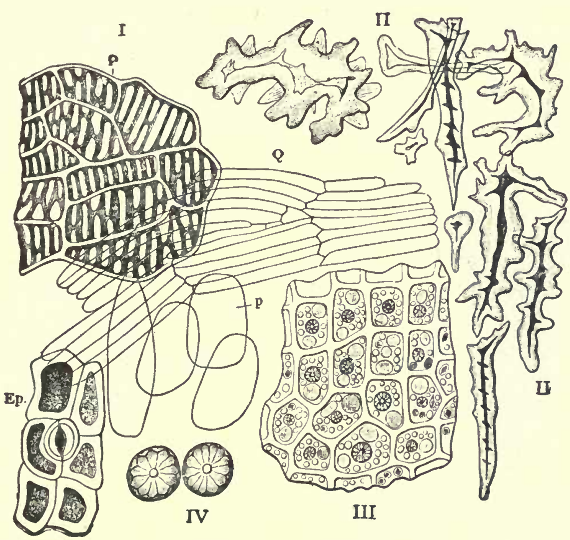


FIG. 136. Hollow Seed (*Bifora radians*). *I* pericarp in surface view showing *Ep* epicarp, *p* parenchyma, *Q* cross cells, and *P* reticulated cells (endocarp); *II* stone cells from sclerenchyma layer of pericarp, isolated by maceration; *III* endosperm showing aleurone grains; *IV* aleurone grains containing calcium oxalate rosettes. (VOGL.)

2. *The Mesocarp* consists of a dense sclerenchyma zone between outer and inner multicellular parenchyma layers (*p*). Many of the scleren-

chyma cells after maceration display characteristic side branches (*II*). Curious netted cells form the innermost layer of the mesocarp.

3. *The Endocarp* consists of narrow cross cells (*Q*).

The Spermoderm lacks distinctive elements.

The Endosperm (*III*) contains aleurone grains with conspicuous rosettes of calcium oxalate (*IV*).

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Vogl (45).

CORNFLOWER.

European grain fields are often infested with the plants of the cornflower (*Centaurea Cyanus* L. order *Compositæ*).

The achene is light gray, about 4 mm. long, and bears a pappus of tan-colored bristles, also about 4 mm. long (Fig. 137).

HISTOLOGY.

The Pappus bristles are made up of bundles of narrow, sclerenchyma fibers, some of which are prolonged into upwardly directed barbs.

Pericarp and **Spermoderm** are united, forming a leathery hull.

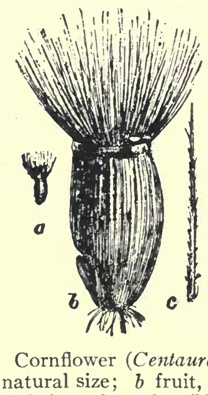


FIG. 137. Cornflower (*Centaurea Cyanus*). *a* fruit, natural size; *b* fruit, enlarged; *c* pappus bristle, enlarged. (NOBBE.)

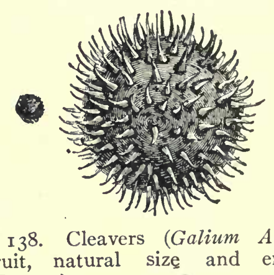


FIG. 138. Cleavers (*Galium Aparine*). Fruit, natural size and enlarged. (NOBBE.)

1. *Epicarp.* The cells have thick, porous, sclerenchyma walls, and are arranged end to end in longitudinal rows.

2. *Sclerenchyma Cells*, similar to those of the epicarp but of smaller diameter, form several layers.

3. *Crystal Cells.* Beautiful bar-shaped, monoclinic crystals are present in great numbers in an ill-defined layer on the inner surface of the sclerenchyma coat. After boiling the seed with 1¼ per cent alkali, this together with the first two layers may be readily stripped off from the seed.

4. *The Palisade Cells* of the fourth layer are about 75 μ high and have thick brown walls. They separate from one another on maceration in alkali.

5. *Parenchyma.* The several layers of compressed cells, on treatment of sections with Javelle water, expand to their normal size. Through this tissue passes the raphe.

The Endosperm consists of a single layer of aleurone cells.

Embryo. The aleurone grains are exceedingly interesting because of their warty outer surface. They are globular or ellipsoidal, varying to 18 μ in length, and inclose numerous globoids.

DIAGNOSIS.

The elements of value in diagnosis are the upwardly barbed bristles, the sclerenchyma layer with crystal cells on the inner surface, the palisade cells, and the warty aleurone grains of the embryo.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Harz (18); Villiers et Collin (42).

CLEAVERS.

A number of plants of the genus *Galium* (order *Rubiaceæ*), known as cleavers, bed-straws, etc., are characterized by their slender square stems provided with numerous small prickles. The fruit of *G. Aparine* L. is rounded, 2–3 mm. in diameter, and hollow with a small hole on one side connecting with the inner cavity. The surface is roughened with minute hooked hairs (Fig. 138). The thin pericarp and spermoderm inclose a horny endosperm in which is embedded a crescent-shaped embryo. Other species of the same genus have similar fruits, although in some species they are of smaller size and without prickles.

HISTOLOGY.

Pericarp (Fig. 139). On boiling with 1¼ per cent alkali, the pericarp readily separates as a gray skin.

1. *The Epicarp* is highly characteristic owing to warts (*IV*), the stomata, and the large hairs, each with a broadly conical base and a hooked apex.

2. *Mesocarp.* A thin-walled tissue, for the most part of spongy parenchyma, forms the thin mesocarp. Fibro-vascular bundles ramify

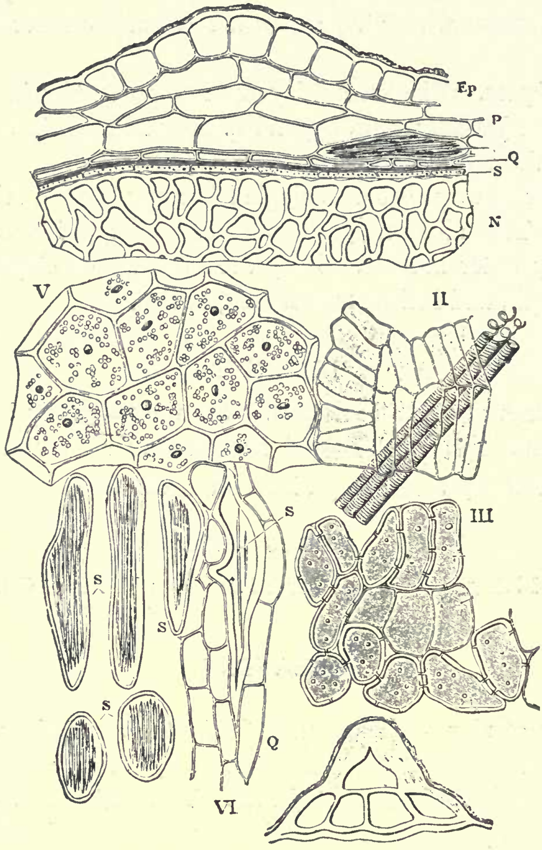


FIG. 139. Cleavers. *I* cross section of fruit. The pericarp consists of *Ep* epicarp, *P* mesocarp with *R* raphides cells, and *Q* cross cells or endocarp; *S* spermoderm; *N* endosperm. *II* surface view showing cross cells and spiral vessels. *III* sclerenchymatized parenchyma from mesocarp. *IV* papilla from epicarp. *V* spermoderm in surface view. *VI*, *Q* cross cells in cross section; *s* isolated raphides cells. (VOGL.)

through this tissue. Cells containing large raphides bundles occur here and there (*s*).

3. *The Endocarp Cells* are thin-walled, narrow, and transversely elongated (*II*).

Spermoderm. A single layer of large, polygonal, often elongated cells with conspicuous brown walls constitutes this coat (*V*). Vogl has noted the presence of brown starch-grains 3 μ in diameter.

Endosperm. The exceedingly thick, horny cell-walls of this tissue are very striking.

DIAGNOSIS.

The warty epicarp cells, the hooked hairs, the raphides bundles, the large brown cells of the spermoderm and the horny endosperm are the characteristic elements (Fig. 139).

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Villiers et Collin (42); Vogl (45).

PLANTAIN.

The minute seeds of common plantain (*Plantago major* L. order *Plantaginaceæ*) and the larger seeds of ribgrass or English plantain (*P. lanceolata L.*) are often present as an impurity in flaxseed and other

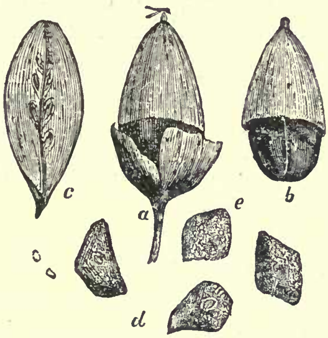


FIG. 140. Plantain (*Plantago major*). *a* fruit with calyx, *b* fruit with cap, and *c* longitudinal section of fruit showing placenta, natural size. *d* seed from inner side and *e* seed from dorsal side, enlarged. (NOBBE.)

economic seeds. The brown seeds resemble in form the wheat kernel, being elongated, convex on one side and grooved on the other (Fig. 140).

The characteristic tissue is the thick-walled, porous endosperm, reminding us of the endosperm of cow-wheat (*Melampyrum*).

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Böhmer (23).

FUNGUS IMPURITIES.

ERGOT.

Ergot is the resting stage (*sclerotium*) of *Claviceps purpurea* Tulasne, a fungus belonging to the order *Pyrenomycetes*. It is formed in the inflorescence of rye and other grasses, entirely replacing the grain.

Ergot is separated from rye for use as a drug in Russia and other continental countries. If the grain is not thoroughly freed from this impurity it is liable to cause certain diseases, although the opinion of authorities differ as to the amount which can be eaten with impunity.

The active stage (*sphacelia*) of the fungus makes its appearance on the ovary during flowering as a soft felt of threads (*mycelium*), bearing numerous brood cells (*gonidia*) in a slimy mass. Later the mycelium at the base of the sphacelia forms a compact mass which develops when mature into the elongated *sclerotium*. At its apex the sclerotium bears an easily detachable cap, consisting of the remnants of the sphacelia of the fungus and the ovary of the grass.

The grains of ergot are 1–3 cm. long 1–6 mm. broad, more or less angular, longitudinally striate, slightly bowed, tapering toward the blunt ends. (Fig. 141.) They are purple-black on the surface, and white with a tinge of pink or purple within.

HISTOLOGY.

The structure, although quite simple, is very different from that of the cereals. As may be seen in cross-sections mounted in turpentine, the compacted hyphæ form a false parenchyma, with narrow cells, rounded cavities and rather thick walls (Fig. 142). The variation in size of the cells is especially noticeable. Fat and proteid matter fill the cells; starch is absent. In one or more of the outer layers both the walls and the cell-contents are of a dark brown color, changing to bright-red with acids and to purple with alkali.

DIAGNOSIS.

The cells of the false parenchyma are distinguished from those of endosperm tissues by their smaller size and the absence of starch; from those of germ tissues by their thicker walls, more variable size and irregular arrangement. The dark brown coloring matter of the outer layers, with

FIG. 141. Ergot (*Claviceps purpurea*), with cap. Natural size. (VOGL.)

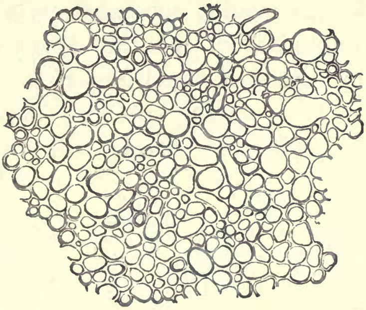


FIG. 142. Ergot. Cross section after extraction of fat. ×300. (MOELLER.)

the reactions noted above, is characteristic. Vogl's hydrochloric acid-alcohol test is described on p. 53.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Berg (3); Böhmer (6, 23); Flückiger (11); Greenish (14); Hanausek, T. F. (16); Macé (26); Meyer (27); Moeller (29, 30, 31, 32); Planchon et Collin (34); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (43, 44, 45); Wigand (46); Wittmack (10).

BELZUNG: Journ. pharm. chim. 1890.

GRUBER: Die Methoden d. Nachw. v. Mutterkorn im Mehl u. Brot. Arch. f. Hyg. 1895, **24**, 228.

HARTWICH: Schweiz. Woch. Chem. Pharm. 1893.

LAGERHEIM: Påvīsande af mjöldrvga i mjöl. Svensk kemisk Tidsk. 1900.

MITLACHER: Versuch einer quantitativen Bestimmung des Mutterkorns im Mehle. Ztschr. allg. österr. Apoth.-Ver. 1902.

MOELLER: Gutachten in der Mutterkornfrage. Ztschr. Nahr.-Unters. Hyg. 1895.

MUSSET: Zum Nachweis von Mutterkorn in Mehl. Pharm. Centralh. 1899.

SPAETH: Pharm. Centralh. 1896, **17**, 542.

SMUTS.

The smuts (*Ustilagineæ*) are parasitic fungi living inside various parts of higher plants. Those which infest grain ripen their resting spores in the ovaries where they form a dark powdery mass replacing the starch of the seed. These spores are more or less globular and have a thick membrane or *episporium* which is smooth or reticulated, brown or colorless, according to the species (Fig. 143).

The Stinking Smuts of Wheat ripen their spores in the wheat kernel, destroying the inner tissues but not the outer hull. The damaged kernels are not greatly different in size from the sound ones, and consequently are not readily separated by screening. Flour made from this grain is contaminated with the spores which, if present in appreciable amount, injure its color and impart to it a disagreeable odor and taste.

The common species (*Tilletia Tritici* (Bjerk) Wint., *T. Caries* Tul.) has reticulated, pale brown, transparent spores reaching 18 μ in diameter

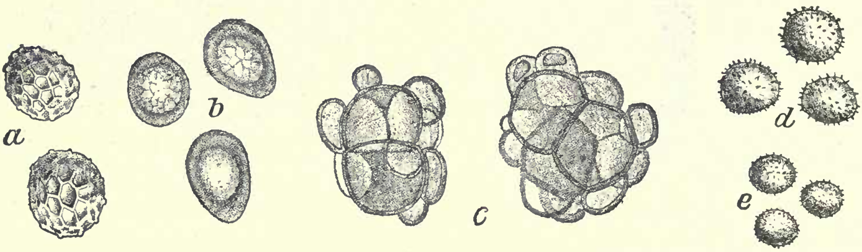


FIG. 143. Spores of Smuts. *a* reticulated-spored stinking smut of wheat (*Tilletia Caries*); *b* smooth-spored stinking smut of wheat (*T. lævis*); *c* rye stalk smut (*Urocystis occulta*); *d* maize smut (*Ustilago Maidis*); *e* loose smut (*Ustilago Carbo*). (MEZ.)

(*a*); a less common species (*T. foetens* (B. & C.) Trel., *T. laevis* Kühn) has smooth spores (*b*).

Rye Smut (*Tilletia Secalis* Kühn) is a rarer species, occurring chiefly in Europe. The reticulated spores are 20–25 μ in diameter.

Loose Smuts. Several species of loose smuts, formerly classed together as *Ustilago Carbo* Tul., attack the fruit of wheat, oats and barley. As they destroy, not only the starchy inner portion of the kernels, but also the hull, the spores (*e*), which vary up to 8 μ, escape during harvesting and seldom contaminate the grain or the flour made from the grain. The following species, infesting respectively wheat, oats and barley, have been described: *U. Tritici* (Pers) Jens, *U. Avenæ* (Pers) Jens, *U. nuda* (Jens) Kell. & Sw.

Maize Smut (*U. Zeæ* (Bechm.) Ung., *U. Maidis* Lév.) develops in the ear of maize, forming an irregular sack filled with a dust consisting of dark brown spores (*d*), 8–14 μ in diameter, with numerous papillæ on the surface.

BIBLIOGRAPHY.

CLINTON: North American Ustilagineæ. Jour. Myco. 1902, 8, 128.

PART III.

OIL SEEDS AND OIL CAKES.

OIL SEEDS.

All fruits and seed in which the reserve material is largely in the form of oil or fat properly belong under this head, although for convenience the cocoanut and other oleaginous nuts are described in Part V, and the peanut, which contains starch as well as oil, with other legumes in Part IV. The mustards are not only oil seeds but also spices.

As a rule the oil is contained largely in the embryo, but in the linseed it is about equally divided between the endosperm and the embryo, while in the olive it is largely in the pericarp. In addition to oil the seeds contain large amounts of proteids in the form of aleurone grains.

Oil-seed Products.

The most important products of the oil seeds are the expressed oils, but many of the cakes or residues of the oil presses, like the by-products of flour mills, starch factories, breweries and distilleries, are of great value as cattle foods. Castor pomace is utilized as a nitrogeneous fertilizer, and ground cottonseed cake or cottonseed meal both as a cattle food and a fertilizer. Mustard cake is employed both as a drug and a condiment.

Some seeds are decorticated before expressing the oil, others are pressed whole and the hulls are either separated from the cake after grinding, as for example in the manufacture of mustard flour, or are not separated at all.

Since oil cakes and oil meals are rich in protein and also in fat, notwithstanding the removal of the larger part of this latter constituent, they are known as concentrated feeds.

Starch being entirely absent in true oil seeds when fully ripe, its presence in the cake indicates adulteration with starchy material or at least contamination with weed seeds. Peanut cake, however, being a by-product of a starchy legume, contains a considerable amount of starch, while on the other hand, maize cake, although a cereal product, is free from starch.

The hulls separated from cottonseed, sunflower seed and some other seeds are utilized as adulterants of cattle foods, and mustard hulls are employed as adulterants of spices and prepared mustard.

The dried residues from the manufacture of some of the essential oils are also non-starchy materials similar to those here considered.

METHODS OF EXAMINATION.

Preliminary Examination. Each oil-cake has certain physical characteristics, such as color, odor, texture, deportment with water, etc., which can be learned only by experience. For example, maize cake has a characteristic taste and odor; cottonseed cake a characteristic color; most cruciferous products develop an odor of mustard oil on mixing with water; linseed cake becomes slimy by the same treatment; and so on.

Foreign seeds, fragments of hulls and other constituents may often be found by macroscopic examination of the unground material or of the coarser grades obtained by sifting. These, if not identified by the naked eye or under the lens, are reserved for microscopic examination.

Cold-water Test. The presence of a large excess of hulls in cottonseed meal is easily disclosed by mixing 5 grams of the ground material with 100 cc. of cold water, and comparing the deposit of black hulls, which immediately settles from the yellow suspended matter, with that obtained by the same method from samples of known composition.

This simple process is also useful in the examination of other oil cakes as well as some cereal products, and serves not only to detect hulls but also added mineral matter.

Collin and Perrot's Method[1] of preliminary examination is as follows: Boil 2 grams of the powdered material 10 minutes with 60 cc. of water to which are added 10–12 drops of concentrated potash solution. Allow to settle 7 or 8 minutes, decant and wash twice with water by decantation. The last decantation should leave 15–20 cc. of water in the dish, which, given a gentle gyratory motion causes the particles of the residue to deposit according to their density. These particles are examined as to their physical properties, especially their color and hardness, and are afterwards prepared for microscopic examination.

Chemical Analysis. Tests for starch or starchy adulterants are made by boiling a small quantity of the material with water, cooling and adding a few drops of potassium iodide iodine.

[1] Les Residus Industriels, etc. Paris, 1904, 35.

Quantitative determinations of starch are laborious and only necessary in exceptional cases, but determinations of protein ($N \times 6\frac{1}{4}$), fat and crude fiber are easily made and are essential for the proper valuation of the material. The addition of starchy substances tends to diminish the percentage of protein and fat without greatly altering the percentage of crude fiber, while the addition of hulls or woody adulterants tends to increase the percentage of fiber at the expense of both the protein and fat.

Microscopic Examination. Starch grains being absent, except in peanut cake and in cake made from unripe or impure seeds, the microscopist must rely largely on the structure of the hulls, or in exceptional cases on the characters of the aleurone grains. The treatment preliminary to the microscopic examination is also very different from that employed for starchy products. Digestion with diastase or boiling with dilute acid is obviously irrational in products containing no starch, but on the other hand, extraction with ether or a similar solvent is often necessary owing to the presence of considerable fat, and treatment with alkali to remove the proteid matter is usually desirable.

Direct Examination of the powdered material in water is useful chiefly in detecting foreign matter containing starch. As starch grains are liable to be confused with oil drops and proteid grains, addition of iodine tincture is advisable.

Addition of alkali facilitates the examination of the tissue by dissolving the proteid grains, saponifying or emulsifying the oil, and swelling the cell-walls. Mounting in a drop of concentrated sulphuric acid aids in identifying cottonseed meal, as the resin masses become bright red in this reagent.

Chloral hydrate serves to detect the hulls of wild mustard by imparting a beautiful cherry-red color to the contents of the palisade cells. These and a few other reactions are of value in diagnosis, but as a rule reagents serve merely to clear the tissues, thus facilitating their examination.

Fragments of the hulls picked out from the unground material are sectioned, scraped, macerated or otherwise treated and examined in water, dilute alkali or some other suitable medium.

Ether Extraction preliminary to examination in water or to treatment by Hebebrand's method may be performed on a filter or by decantation in a beaker. If more complete extraction is desirable the continuous apparatus of Soxhlet, Tollens or Johnson may be employed.

Hebebrand's Method[1] for clearing sesame cake and other materials with delicate tissues which would be destroyed by Beneke's methods is as follows:

Extract a portion of the material with ether and grind so as to pass a 0.5 mm. mesh. Mix 0.5 gram of the extracted and finely ground material with 10–15 cc. of sodium carbonate solution (7 grams of the dry salt in 100 cc. of water) and pass chlorine gas into the mixture, taking care that the solution remains alkaline. After 2–15 minutes, according to the material, dilute with water, allow the fragments of tissues to settle, decant off the liquid and wash twice by decantation. Examine the residue in water or some other suitable solvent.

Chlorine gas is conveniently prepared by treating the so-called "chloride of lime cubes" with dilute hydrochloric acid in the special form of generator supplied by Peters and Rost, Berlin. Sufficient gas for clearing one sample may be generated from a single cube.

Beneke's Method[2] may be used for accumulating and clearing tissues of the pericarp and spermoderm, provided these tissues are strongly developed. It is not suited for clearing delicate tissues.

It is described at some length by the author, but the following directions will be found sufficient: Heat in a porcelain dish, with constant stirring, about 5 grams of the material with 30 cc. of concentrated hydrochloric acid and 10 cc. of concentrated nitric acid until the liquid begins to foam. Add at once considerable cold water, and filter on a piece of fine mull and wash with water.

Rinse back into the dish with 60 cc. of water, add 30 cc. of concentrated sodium hydrate and heat until the solution begins to boil. Dilute with cold water, filter and wash as before. Mount the residue and examine.

Collin and Perrot's Method is described under "Preliminary Examination" (p. 170).

CRUCIFEROUS SEEDS (*Cruciferæ*).

The flowers of cruciferous plants are very similar in all the species, having, as the family name suggests, four regular petals and four sepals.

Systems of classification depend largely on the characters of the pods and seeds.

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[1] Beitrag zur mikroskopischen Untersuchung von Nahrungs- u. Futtermitteln. Forschungsber. f. Lebensm. 1897, 306. Landw. Vers.-Stat. 1898, **51**, 74.

[2] Anleitung zur mikroskopischen Untersuchung der Kraftfuttermittel. Berlin, 1886, 38.

The pods, known as siliques when long or silicles when short, are commonly divided into two cells by thin, longitudinal partitions, passing through the two parietal placentæ. When ripe the outer walls of each pod separate from the partition as two valves, the seeds remaining with the partition.

The campylotropous seeds consist entirely of spermoderm and embryo without endosperm, and usually have a pungent taste.

As seen in cross section the arrangement of the cotyledons (=) with reference to the radicle (o) may be accumbent (o =) incumbent (o ||) or conduplicate (o > >). In some species the cotyledons are coiled or folded endwise, the cross section appearing thus: o || ||, o || || || etc.

Under a lens the seeds of some species show numerous shallow pits, the ridges between the pits forming delicate reticulations.

Microscopic Characters of Cruciferous Seeds.

The Spermoderm (Fig. 146) normally has four layers, but in many species the first and second layers at maturity form a structureless membrane with no evidence of cells.

1. *The Epidermal Cells* (*ep*) when present are polygonal, and usually have thin walls. In certain species on adding water a mucilaginous substance is evident which D'Arbaumont, contrary to the formerly accepted view, has shown is formed from cell-contents, not from the cell-wall.

D'Arbaumont divides the phenomena observed in numerous species on addition of water into four groups:

(1) Complete diffusion of the contents.

(2) Diffusion of the lateral layers, an axial cylinder remaining unchanged.

(3) Simple swelling of the layers.

(4) The mucilage, owing to the pressure developed in the cell, bursts through the outer wall forming a body of definite shape.

The appearance of the mucilage after addition of water, whether in the cell or after escaping, is of considerable value in diagnosis.

2. *The Subepidermal Layer,* or outer parenchyma layer, consists of one or two cell layers of thin-walled polygonal elements often of considerable size. In some species, notably white mustard, the cells (Fig. 144, *se*) are collenchymatously thickened at the angles.

3. *The Palisade Cells* (*b*), or beaker cells, form the most striking layer of the seed. The inner walls and at least the inner portions of the radial

walls are more or less strongly thickened, giving the cells in cross section a beaker-like appearance. These thickened walls are either yellow or brown, according to the color of the seed.

In certain species this layer in surface view displays dark meshes (Fig. 149) corresponding to the reticulations of the spermoderm. This appearance is due to the greater height of the palisade cells (Fig. 146, *se*) in the meshes, and is valuable in diagnosis.

As seen in surface view the cells vary greatly in breadth (3–100 μ) and have a sharply polygonal outline and more or less rounded lumen. Owing to their polygonal form and thick walls they present a mosaic-like appearance.

4. *The Pigment Cells* (*g*) are in one or more layers, and contain in the case of brown seeds, a dark colored material. In surface view they lack characteristic features.

Endosperm. Most authors have described the remaining layers of the hull as inner spermoderm; Gruinard and also Gram, however, have demonstrated that they belong to the endosperm.

1. *Aleurone Cells* (*K*) similar to those found in the cereals form the outer portion of the endosperm. In most seeds only a single cell layer is present except under the micropyle where there are two or even more layers, and under the hilum where they are entirely absent.

2. *Obliterated Parenchyma* makes up the remainder of the endosperm.

The Embryo tissues are thin-walled and contain aleurone grains and fat.

Chief Characters.

None of the common cruciferous seeds contain starch, and all have a palisade layer of beaker cells forming a brown or yellow mosaic, and an endosperm with a single layer of aleurone cells.

Of diagnostic value when present are the epidermal cells with mucilaginous contents, the subepidermal layer of collenchyma cells and the pigment layer.

Analytical Key to Cruciferous Seeds.

A. Spermoderm yellow.

1. Epidermal cells with mucilaginous contents; subepidermal layer collenchymatous........................White Mustard (*Sinapis alba*).
2. Epidermal cells with mucilaginous contents; subepidermal layer not evident..(*Eruca sativa.*)

3. Epidermal and subepidermal layers form a structureless membrane (not cellular)................Indian Colza (*Brassica campestris* var. *Sarson*).

B. Spermoderm brown.

(*a*) Palisade layer with reticulations.

* Epidermis cellular, usually with mucilaginous contents.

4. Subepidermal cells large, not collenchymatous; palisade cells red brown, narrow (usually 3–10 μ)....................Black Mustard (*B. nigra*).

5. Subepidermal cells collenchymatous; palisade cells red brown (*Sinapis dissecta*).

6. Subepidermal cells very large, collenchymatous; palisade cells red-yellow. Wild Radish (*Raphanus Raphanistrum*).

7. Subepidermal cells indistinct or lacking; palisade cells red-brown, broader than in 4........................Sarepta Mustard (*B. Besseriana*).

8. Subepidermal layer lacking; palisade cells after treatment with acid and alkali, yellow-brown; reticulations very narrow..Palai Rape (*B. rugosa*).

** Epidermis not cellular.

9. Palisade cells with lumen thicker than double walls; reticulations narrow; aleurone cells often in two layers. Brown Indian Rape (*B. Napus* var. *dichotoma*).

10. Palisade cells with lumen narrower than double walls; reticulations narrow; aleurone cells in one layer..........Indian Mustard (*B. juncea*).

(*b*) Palisade layer with ribs, not reticulations.

11. Epidermal and subepidermal layers not cellular. Field Pennycress (*Thlaspi arvense*).

(*c*) Palisade layer without distinct reticulations or ribs; epidermis cellular with mucilaginous contents.

* Mucilage escapes as long tapering columns.

12. Epidermal and palisade cells broad (up to 90 μ), walls 15–20 μ. False Flax (*Camelina sativa*).

13. Radial walls of epidermis thick and porous; palisade cells broad with broad lumen ....(*Erysimum orientale*).

** Mucilage escapes as long columns broadened at the outer ends.

14. ....Pepper Grass (*Lepidium campestre, L. sativum*).

*** Mucilage in axial columns seldom escaping from the cells.

15. Palisade cells up to 60 μ broad with broad lumen. Shepherd's Purse (*Capsella Bursa-Pastoris*).

16. Palisade cells narrow, thickened only at inner ends (*Sisymbrium officinale*).

**** Mucilage never escapes from cells.

17. Mucilage in layers in outer portions of cells; palisade cells with broad lumen, each containing a single crystal, (rarely a cluster)..(*Barbarea vulgaris*).

18. Mucilage shows honeycomb structure; spermoderm blood-red on heating with chloral.............................Charlock (*B. Sinapistrum*).

BIBLIOGRAPHY.

See General Bibliography, pp. 671-674· Böhmer (6, 23); Collin et Perrot (9).

ABRAHAM: Bau und Entwicklung der Wandverdickungen in den Samenoberhautzellen einiger Kruziferen. Jahrb. f. wissensch. Bot. 1885, **14**, 559.

D'ARBAUMONT: Note sur les téguments séminaux de quelques Crucifères. Bot. Jahresb. 1890, **18**, I Abt., 663. Journ. de micrographie. 1891, **15**, 212. Bull. Soc. Bot. de France. 1891, **38**, 67.

BURCHARD: Ueber den Bau der Samenschale einiger Brassica- und Sinapis-Arten. Jour. f. Landw. 1894, **42**, 125. 1896, **44**, 337.

CLAES et THYES: Morphologie comparée des testes des Brassica: oleracea, napus, rapa et nigra et des Sinapis: alba et arvensis. Bull. de l'agric. 1891, **7**, 253.

GRAM: Ueber Rapskuchen und deren Verunreinigung. Landw. Vers.-Stat. 1898, **50**, 449.

GUIGNARD: Recherches sur le développement de la graine et en particulier du tégument séminal. Jour. Bot. 1893, **7**.

v. HÖHNEL: Bau der Samenschale der vier cultivirten Brassicaarten; in Haberlandt. Wissensch.-prakt. Untersuchungen auf dem Gebiet des Pflanzenbaues. 1875, **1**, 171.

KINZEL: Ueber die Samen einiger Brassica- und Sinapis-Arten, mit besonderer Berücksichtigung der ostindischen. Landw. Vers.-Stat. 1899, **52**, 169.

KOBUS: Kraftfutter und seiner Verfälschung. Landw. Jahrb. 1884, **13**, 813.

PAMMEL: On the Seeds and Spermoderm of some Cruciferæ. Amer. Monthly Mcr. Jour. 1897, I.

PIETERS and CHARLES: The Seed Coats of Certain Species of the Genus Brassica. U. S. Dep. Agr., Div. Bot. Bull. **29**, 1901.

PRAIN: A Note on the Mustards cultivated in Bengal. Agricultural Ledger 1898, No. 1.

SCHRÖDER: Untersuchung des Samens der Brassica-Arten und Varietäten. Landw. Vers.-Stat. 1871, **14**, 179.

SEMPOLOWSKI: Ueber den Bau der Schale landwirthschaftlich wichtiger Samen. Landw. Jahrb. 1874, **3**, 823.

TSCHIRCH: Entwicklungsgeschichtliche Studien. Schw. Woch. Chem. Pharm. 1897, **35**, No. 17.

VUILLEMIN: Beiträge z. Kenntnis der Senfsamen. Diss. Zürich, 1904.

WOLFF: Zur Kentniss der Senfsorten des Handels. Pharm. Ztg. 1893, **38**, 761.

WHITE MUSTARD.

Yellow or white mustard (*Sinapis alba* L.), a native of Europe, is grown for its seed in various parts of Europe and America, particularly in England, Holland, Germany, and California.

The nearly globular seeds are 2–3 mm. in diameter and are characterized by their buff color. Examined under a lens they have a finely granular but not reticulated surface. Like all the mustards they are campylotropous. Cross sections slightly magnified show the embryo consisting of the radicle and two large conduplicate cotyledons.

In addition to sinapin sulphocyanide and the enzyme, myrosin, both of which are found also in black mustard, white mustard contains a glucoside, sinalbin, which, in the presence of water, is split up by myrosin into sinapin hydrosulphate, dextrose, and sinalbin sulphocyanide, the latter being a non-volatile principle with a biting taste.

HISTOLOGY.

Cross sections are prepared after embedding the dry seed in hard paraffine. For the study of the epidermis these are mounted in alcohol, and water is cautiously drawn under the cover-glass during observation. The same sections, after treatment with alkali, serve for the study of the other layers of the spermoderm. Sections mounted in turpentine or strong glycerine are adapted for studying the aleurone grains of the endosperm and embryo. Surface preparations of the spermoderm and endosperm are obtained by heating with dilute alkali and scraping with a scalpel.

Spermoderm (Figs. 144 and 145). 1. *The Epidermis* (*ep*) consists of polygonal, isodiametric mucilage cells ranging up to 100 μ in diameter.

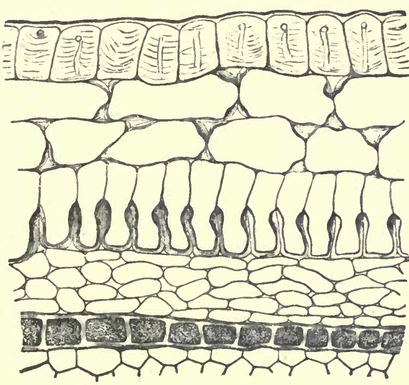


FIG. 144. White Mustard (*Sinapis alba*). Cross section of seed. Spermoderm consists of *ep* epidermis, *se* collenchyma, *b* palisade cells, and *p* parenchyma; endosperm consists of *P* aleurone cells and *i* compressed cells. (MOELLER.)

Cautious treatment of alcohol mounts with water displays the mucilaginous substance deposited in layers with a distinct cylindrical cavity in the axis of each cell. In surface view, the primary walls appear indistinctly beaded and the mucilage layers show concentric rings and often radial clefts.

2. *Collenchyma* (*se*). Characteristic of white mustard are the subepidermal cells with collenchymatously thickened angles. These are of about the size of the epidermal cells, and are usually in two layers.

3. *Palisade Cells* (*b*). Radially elongated cells thickened in the inner halves form the most conspicuous layer of the seed, the thickened walls forming a kind of cup, hence the name "beaker cells." Of great diagnostic importance are the colorless, thickened walls, which in most economic cruciferous seeds are brown. As these cells are of nearly uniform height, pronounced reticulations are not evident on the seed. In surface view the cells are sharply polygonal, varying up to 15 μ in diameter.

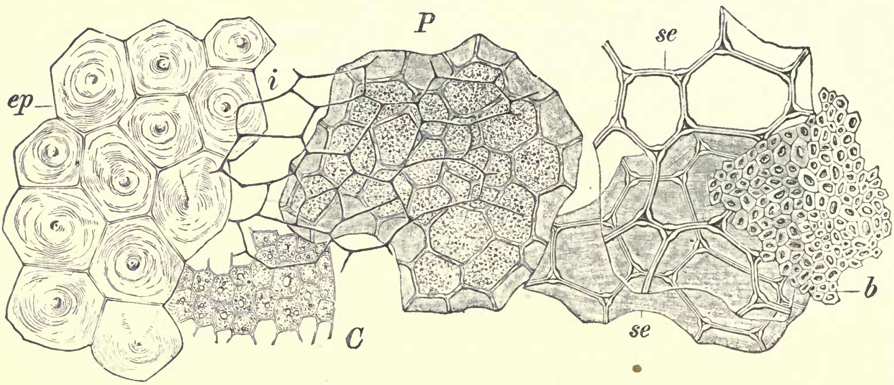


FIG. 145. White Mustard. Elements of seed in surface view. *ep* epidermis, *se* collenchyma, *b* palisade cells, and *p* parenchyma, of spermoderm; *P* aleurone cells of endosperm; *C* cotyledon tissue. (MOELLER.)

4. *Inner Layers* (*p*). Two or more layers of thin-walled isodiametric or elongated cells complete the spermoderm. These cells, unlike the corresponding layer of many cruciferous seeds, do not contain a pigment.

Endosperm (Figs. 144 and 145). 1. *Aleurone Cells* (*P*). These cells resemble closely the aleurone cells of cereals. They are 20–40 μ in diameter, have thick, colorelss walls, and contain fat globules and polygonal or rounded aleurone grains 1–4 μ in diameter.

2. *Obliterated Parenchyma* (*i*). The remainder of the endosperm consists of compressed cells without evident cellular structure.

Embryo (Fig. 145, *C*). Cross sections show that not only the cells on the inner sides of the cotyledons (the upper sides after sprouting) are typical palisade cells, but all the mesocarp cells are more or less elongated. These cells in the mature seeds contain fat and aleurone grains, never starch. The aleurone grains are either isodiametric or oblong. In the outer epidermis the isodiametric grains are about 3 μ in diameter, in the inner layers 6–10 μ. The oblong grains are about the same width as those of isodiametric form, but are often twice or three times as long. As the cells are but little broader than the grains, each usually contains but a single row of grains, which are often so crowded that the sides in contact are more or less flattened. Each grain contains numerous minute globoids.

As was first noted by Gruinard, occasional cells of both the cotyledons and radicle contain grains without globoids, which, in sections previously extracted with ether, are colored bright crimson-red on gently heating with Millon's reagent and golden-yellow on treatment in the cold with iodine. These cells are believed by both Gruinard and Gram to be the seat of the myrosin, and are designated "myrosin-cells."

DIAGNOSIS.

The color of white mustard seed serves to distinguish it from all black or brown cruciferous seeds both in a macroscopic and microscopic way. Seeds of white Indian rape (*B. campestris* L. var. *Sarson* Prain) sometimes used as an adulterant, although of the same color as white mustard, are distinguished macroscopically by the more pronounced ridge over the radicle, and microscopically by the homogenous epidermis, the absence of a collenchymatous subepidermal layer and the large size of the palisade cells.

White Mustard Flour is prepared either from the whole seeds, or more commonly from the cake remaining after expressing the oil. Although the hulls are largely removed, fragments are always present in small amount and are distinguished from the brown hulls of black mustard and other related seeds by their yellow color. The bulk of the organized material consists of proteid and fat. Examined in turpentine, or after extraction of the fat, in iodine tincture, the aleurone grains are clearly differentiated. White and black mustard flour are usually blended, as noted under black mustard.

Prepared Mustard. See Black Mustard (p. 183).

White Mustard Hulls, separated in the manufacture of mustard flour, serve as an adulterant for prepared mustard and various spices.

The elements of the hulls of chief value in diagnosis are the colorless, distinctly cellular epidermal layer (Fig. 145, *ep*) with mucilaginous contents, the collenchymatous subepidermal layer (*se*) and the yellow palisade cells (*b*) without evident reticulation.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Berg (3); Blyth (5); Böhmer (10); Flückiger (11); Greenish (14); Hanausek T. F. (16, 48); Harz (18); Hassall (19); Leach (25); Macé (26); Meyer, A. (10, 27, 28); Moeller (29, 30, 31, 32); Planchon et Collin (34); Schimper (37); Tichimirow (38); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (43, 45).

Also see Bibliography, of Cruciferæ, p. 176.

HARZ: Ueber eine neue Verfälschung des weissen Senfes. Bot. Centralb. 1887, 8, 249.

STEFFECK: Ein neues Fälschungsmittel des weissen Senfes (*Sinapis alba*). Landw. Vers.-Stat. 1887, **33**, 411.

BLACK MUSTARD.

Brown or black mustard (*Brassica nigra* (L.) Koch) is cultivated in many parts of Europe, Asia, and America. The globular, campylotropous seeds are 1–1.5 mm. in diameter and vary in color from light brown to nearly black. Under a lens they are beautifully reticulated. The husk or hull of the seed consisting of the spermoderm and the thin endosperm, envelops the embryo with its conduplicate cotyledons.

The sharp taste of black mustard is due chiefly to allyl sulphocyanide, or volatile mustard oil. This does not, however, exist ready formed in the seed; but is developed by the action of an enzyme, myrosin, on a glucoside, sinigrin (potassium myronate), in the presence of water.

HISTOLOGY.

Cross-sections and surface mounts are prepared as described under white mustard.

Spermoderm (Figs. 146, 147 and 148). 1. *The Mucilage Cells* (*ep*) of the epidermis are polygonal in form and of large size (50–100 μ). If sections are first mounted in alcohol, and water is carefully drawn under the cover-glass, the mucilaginous substance is seen to be deposited in layers. Gentle warming with alkali removes this substance, and also aids in clearing the remaining layers.

2. *Subepidermal Cells* (*se*). Beneath the epidermis are thin-walled cells even larger than those of the epidermis, the radial walls of which correspond with the reticulations of the seed and the highest cells of the next layer.

3. *Palisade Cells* (*b*). Cross sections show that the palisade or beaker cells are of unequal height, causing the reticulated appearance

of the seed and the conspicuous, dark meshes seen in surface view (Fig. 149). Focusing on the extreme outer end of the highest cells,

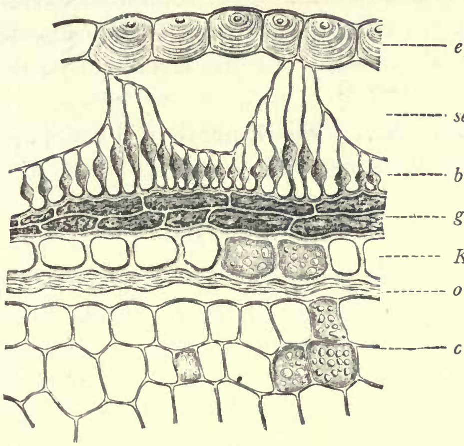


FIG. 146. Black Mustard (*Brassica nigra*). Cross section of seed. Spermoderm consists of *ep* outer epidermis, *se* giant cells or subepidermal layer, *b* palisade cells and *g* pigment cells; endosperm consists of *K* aleurone cells and *o* compressed cells; *c* cotyledon. (MOELLER.)

the thin walls of these cells form chains following the contour of the meshes. Sometimes a transparent skin, consisting of the epidermis and the outer thin-walled portion of the palisade cells, breaks away from the remainder of the spermoderm, presenting the appearance shown

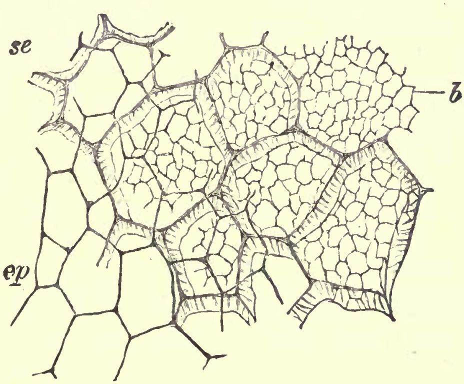


FIG. 147. Black Mustard. Surface view of *ep* epidermis, *se* giant cells and *b* outer portion of palisade layer. ×160. (MOELLER.)

in Fig. 147. As seen in surface view, the cells are isodiametric, 4–10 μ in diameter, or elongated, reaching a maximum length of 20 μ.

4. *Pigment Cells* (*g*). One, sometimes two, layers of cells with brown contents form the inner coat of the spermoderm. In surface view the cells are either isodiametric or somewhat elongated, often reaching a length of 75 μ. Ferric chloride colors the cell-contents blue. The color of the seed is due partly to this layer and partly to the palisade layer.

The Endosperm (*K*, *o*) **and Embryo** (*C*) are practically the same as described under white mustard.

DIAGNOSIS.

Black Mustard Seed is distinguished from that of white mustard by its darker color, from Sarepta mustard by its smaller size, and from rape by its smaller size and distinctly reticulated surface. Charlock (*B. Sinapistrum* Boiss.), a common weed, especially in the grain fields of North and South Dakota, is often substituted for black mustard.

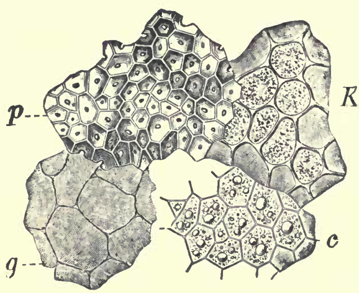


FIG. 148. Black Mustard. Surface view of *p* inner portion of palisade layer, *g* pigment cells, *K* aleurone cells, and *c* cotyledon tissues. ×160. (MOELLER.)

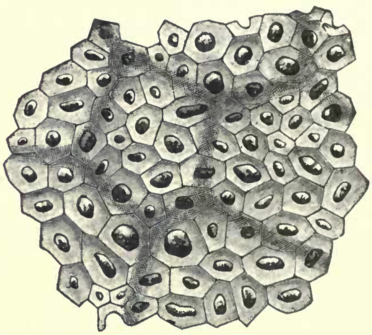


FIG. 149. Black Mustard. Palisade cells in surface view. (MOELLER.)

Although of about the same size, the seed is not reticulated, and is usually of a darker color.

The unequal height of the palisade cells (Fig. 149), the highest corresponding to the reticulations of the seed and the outline of the subepidermal cells, and their small size, are especially characteristic of black mustard.

Black Mustard Flour, like that made from white mustard, is usually prepared from the cake, with the removal of the hulls. It is a common practice to blend the flour of both black and white mustard, the excess of myrosin in the latter serving to convert the last traces of potassium myronate of the former into allyl sulphocyanide. The flour of black mustard consists in large part of embryo substance, with occasional fragments of the hulls (spermoderm). The aleurone grains may be examined in oil of turpentine, or, after the removal of the fat, in strong glycerine. Fragments of the spermoderm, owing to their darker color, cannot be confounded with those of white mustard. The palisade cells (Fig. 149) are smaller than those of Sarepta mustard, rape, charlock, and many cruciferous seeds, and the thin-walled outer portion of the highest of these cells forms a characteristic network of chain-like meshes (Fig. 147, *se*). Charlock is detected by the cherry-red color imparted to fragments of the hulls by treatment with chloral hydrate (p. 185).

The common adulterants of mustard flour are wheat flour and other cereal products, gypsum and other mineral substances, turmeric and coal-tar dyes. Since mustard contains no starch, farinaceous adulterants are especially easy of detection. Turmeric is identified by the bright yellow particles which change to reddish-brown on treatment with alkali.

Prepared Mustard. Mustard paste, also known as German or French mustard, is a mixture of flour from one or more kinds of mustard with spices, salt and vinegar. It is often adulterated with starchy matter, mustard hulls, dyes and preservatives.

Black Mustard Hulls, obtained as a by-product in the manufacture of the flour, are used not only as adulterants of mustard paste, but of pepper and other spices.

The palisade cells are the most striking elements. The inner thick-walled portion of the layer forms a brown mosaic (Fig. 149) with darker reticulations, while the outer thin-walled portion displays a delicate network (Fig. 147).

BIBLIOGRAPHY.

See Bibliography of White Mustard, p. 180.

SAREPTA MUSTARD.

In Russia the so-called Sarepta mustard (*B. Besseriana* Andr.) is grown in considerable quantities. Formerly this species and Indian mustard (*asi-rai*) were both known as *B. juncea* Hook. f. et Thoms., but Prain has shown that these two plants are distinct, and has reserved the specific name *juncea* for the Indian species.

The seed resembles black mustard except that it is somewhat larger (1–1.8 mm.). Distinct reticulations are clearly seen under a lens.

In microscopic structure also, the seed agrees in most points with black mustard; the palisade cells, however, are somewhat wider (often triangular) and the subepidermal layer is much less distinct, often being entirely obliterated.

BIBLIOGRAPHY.

See Bibliography of Cruciferæ, p. 176: Böhmer; Kinzel.

Tichomirow: Die Struktur der Samenschale von *Brassica juncea* Hook. Pharm. Centralh. 1900, **41**, 510.

CHARLOCK.

Grain fields, both of the Old and New World, are often infested by charlock (*Brassica Sinapistrum* Boiss., *Sinapis arvensis* L.), a cruciferous plant with bright yellow flowers. Charlock is especially abundant in the wheat fields of North and South Dakota, Minnesota, and adjoining states, the seeds being almost always present in screenings from this region. A product known in the trade as Dakota mustard consists largely of the seeds of this plant separated from screenings.

The deep brown, nearly black, seeds of charlock are 1–1.5 mm. in diameter. They have a dull surface, but do not appear reticulated, even under a lens.

HISTOLOGY.

This seed differs from other cruciferous seeds in the structure of the mucilaginous substance of the epidermis, and the nature of the contents of the palisade cells.

Spermoderm. 1. *The Epidermal Cells* are 40–75 μ in diameter. Cross sections mounted in alcohol and treated cautiously with water display well-defined radial walls and a radially striated mucilaginous deposit. This latter, in surface view, has a delicately reticulated structure with a central cavity; the reticulations are much the same in size as those formed by the outer radial walls of the palisade cells, but are not so distinct, and disappear entirely on adding sufficient water.

Harz first called attention to this structure, and Gram shows it clearly in his figures.

2. *Subepidermal Layer.* According to these last named authors, this coat consists of two compressed layers, but scarcely any evidence of cellular structure is apparent in the mature seed.

3. *Palisade Cells.* Seen from without, this layer differs from the pali-

sade cells of other crucifers in that the thickened radial walls are hidden from view by the dark brown contents which fills the cell. Waage first noted that the hulls of charlock assume a blood-red color on treatment with chloral hydrate. This characteristic reaction, due to the contents of the palisade cells, is hastened by heating.

Cross sections show that the cells are uniform in height, the radial walls being thickened for only three-fourths of their length. Heating with chloral hydrate causes the outer thin-walled portion to assume its normal shape, and colors the material contained in both the inner and outer portions of the cells a beautiful blood-red hue, contrasting strikingly with the yellow-brown color of the sclerenchyma walls and the pigment layer.

4. *Pigment Layer.* A single row of pigment cells is present. Although the contents are yellowish-brown, the dark color of the seed is due solely to the material in the palisade cells.

Endosperm and Embryo are much the same as in black mustard.

DIAGNOSIS.

The dark, nearly black color of the seeds and the absence of reticulations on the surface distinguish charlock from black mustard; the smaller size of the seeds distinguishes it from rape. The delicately reticulated appearance of the mucilaginous substance in the epidermis is characteristic, but not always clearly evident. Especially striking are the dark contents of the palisade cells, which become blood-red on heating with chloral hydrate.

BIBLIOGRAPHY.

See Bibliography of Cruciferæ, p. 176: Böhmer; Burchard; Collin et Perrot; Gram; Pieters and Charles.

COMMON RAPE.

Of the cruciferous seeds utilized for oil and cattle food, not for condiments, common rape, also known as colza, (*Brassica Napus* L.) is the best known in Europe. Before the advent of petroleum and coal gas, rape oil was burned for illuminating purposes; but at the present time it is used chiefly as a lubricant and for making soap. As the cake yields but a small amount of volatile mustard oil, it is well adapted for feeding animals.

Rape is grown chiefly in Germany, Russia, and Austria-Hungary, to a limited extent in France and Belgium, but seldom in America. There are summer and winter varieties.

The seed is globular, 1.5–2.5 mm. in diameter and is of a dark brown, almost black color. On the surface it is dull but never reticulated, even under a lens, a striking distinction from the seeds of black mustard.

HISTOLOGY.

Rape corresponds in general structure to black mustard, but the *Epidermis* and the *Subepidermal Layer* of the ripe seed form an indistinct coat with little or no evidence of cellular structure.

The Palisade Cells are of nearly uniform height, hence the absence of reticulation such as occur on the seeds of black and Sarepta mustard. Another striking distinction from the mustards lies in the larger size of the palisade cells, which, as seen in surface view, have an average diameter of 20 μ and often reach 30 μ.

Harz states that the diameter of the lumen of each cell is about as great as the breadth of the double walls, whereas in German rape the lumen is usually narrower. Hanausek and Gram confirm this distinction, but Collin and Perrot state that the lumen in German rape is the larger. Pieters and Charles place chief dependence on the more regular height of the palisade cells which varies not more than 3 μ, while in German rape it varies from 5–7 μ.

The faintly reticulated appearance of the spermoderm of German rape which Collin and Perrot regard as the chief means of distinction, is explained by the variation in the height of the palisade cells.

The remaining coats of the spermoderm, also the endosperm and embryo agree in structure with the corresponding coats of black mustard, though myrosin cells are less numerous in the embryo.

DIAGNOSIS.

The characters of chief use in diagnosis are the large size of the palisade cells (maximum diameter 30 μ), their uniform height, and the consequent absence of reticulations. Epidermal cells are seldom distinguishable. Among the foreign seeds of rape cake are false flax (*Camelina sativa*), treacle mustard (*Erysimum orientale*), wild radish (*Raphanus Raphanistrum*), charlock (*Sinapis arvensis*), hedge mustard (*Sisymbrium officinale* and *S. Sophia*), penny-cress (*Thlaspi arvense*), shepherd's purse (*Capsella Bursa-Pastoris*), peppergrass (*Lepidium campestre*), and other cruciferous seeds.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Beneke (2); Böhmer (6, 10, 23); Collin et Perrot (9); Hanausek, T. F. (17, 48); Harz (18); Hassall (19); Moeller (29).

Also see Bibliography of Cruciferæ, p. 176: Burchard; Claes et Thyes; Gram; Kobus; Pieters and Charles; Schröder; Sempolowski; etc.

GERMAN RAPE.

The varieties of German rape (*Brassica Rapa* L.), known in Germany as *Rübsen*, are put to the same uses as common rape.

The differences in microscopic structure of the two species are noted under common rape.

INDIAN COLZA.

Sarson, or Indian colza (*Brassica campestris* L. var. *Sarson* Prain, *Sinapis glauca* Roxb.), has both white and brown seeded varieties, although the latter are rare. The seeds have been introduced into Europe as adulterants of white mustard, which they closely resemble. Kinzel believes that the "Guzerat Raps" of Wittmark belongs under this variety, and it is probable that the same is true of the yellow Indian rape described by Steffeck and the false white mustard to which Harz gave the name *B. Iberifolia.* The seed is without reticulations, and in general appearance closely resembles white mustard.

Unlike white mustard, the epidermis forms a homogeneous layer without evident division into cells, and the subepidermal layer is entirely lacking. In some, if not all varieties, the palisade cells are broader than in white mustard, being about the same size as in common rape.

The cake from this and the three following oil seeds is imported into Europe from India.

According to Kinzel, the chief impurity is the black triangular seeds of *Asphodelus tenuifolius*, which resemble the fruits of black bindweed (*Polygonum Convolvulus*), except that they are transversely wrinkled. The epidermis obtained by scraping the opaque spermoderm is characterized by the thin lamellæ, which appear like 4–6 concentric circles.

BIBLIOGRAPHY.

See Bibliography of Cruciferæ, p. 176: Kinzel.

BROWN INDIAN RAPE.

According to Prain, tori or brown Indian rape is *Brassica Napus* L. var. *dichotoma* Prain.

It is grown both as an oil seed and as a vegetable.

Kinzel states that the epidermis in cross section does not appear cellular, and that the aleurone cells are often in two layers. He further notes that the highest palisade cells form conspicuous but very narrow reticulations, and that the lumens of the palisade cells are as broad as those of European rape.

BIBLIOGRAPHY.

See Bibliography of Cruciferæ, p. 176: Kinzel.

INDIAN MUSTARD.

The Indian plant asi-rai, according to Prain and Kinzel, is *Brassica juncea* Hook. f. et Thoms. It yields a brown seed much like that of black mustard, although somewhat larger. The meshes on the surface are distinctly seen with the aid of a lens.

Unlike Sarepta mustard, the epidermis does not have an evident cellular structure.

BIBLIOGRAPHY.

See Bibliography of Cruciferæ, p. 176: Kinzel.

PALAI RAPE.

The seeds of the plant known in India as palai, palangi or pahari rāi, etc. (*Brassica rugosa* Prain) are brown and finely reticulated.

According to Kinzel, this species is distinguished from all other Indian rapes by the cellular strcuture of the epidermis. Treated with sulphuric acid and alkali, the palisade cells are of a more yellow-brown color than in other varieties.

BIBLIOGRAPHY.

See Bibliography of Cruciferæ, p. 176: Kinzel.

DISSECTED MUSTARD.

Kinzel states that the seeds of *Sinapis dissecta* Lagasca (*Brassica dissecta* Boiss.) frequently occur in Russian linseed and rape seed, as well as in the cake made from these seeds.

Burchard finds that the histological structure is very similar to that of white mustard, the chief differences being that the palisade and pigment layers contain a brown pigment, and the palisade layer displays narrow reticulations, due to the unequal height of the cells.

BIBLIOGRAPHY.

See Bibliography of Cruciferæ, p. 176: Böhmer; Burchard; Gram; Kinzel.

ERUCA.

This plant (*Eruca sativa* Lam.) is a common weed in Southern Europe and India. The seeds are usually yellow, but occasionally are red-yellow or mottled with green-brown spots. The spermoderm is smooth.

Gram notes the following points with regard to the histological structure:

The epidermal cells contain mucilaginous substance in layers with axial columns. The double contour of the walls as seen in surface view is due to a thickening of the outer walls at the edges of the cells. No sub-epidermal layer is evident. The palisade layer has thickened radial walls only in its inner half, where the double walls are about the thickness of the lumen.

BIBLIOGRAPHY.

See Bibliography of Cruciferæ, p. 176: Böhmer; Collin et Perrot; Gram.

FALSE FLAX.

In Germany, Holland, and some other countries, false flax (*Camelina sativa* L.) is sparingly grown for its seed, which yields oil and cake. It also occurs as a weed in flax fields and the seed as an impurity of linseed and rape seed.

The brown seed (Fig. 150) is 1.5 mm. long and about half as broad, its surface being finely granulated but not reticulated. A pronounced longitudinal ridge marks the position of the radicle.

HISTOLOGY.

The Spermoderm (Fig. 151) consists of epidermis, palisade cells, and an inner layer corresponding to the pigment layer of the mustards and rapes. There is no evidence of a subepidermal layer in the ripe seed.

FIG. 150. False Flax (*Camelina sativa*). Seeds, natural size and enlarged. (NOBBE.)

1. *The Epidermal Cells* are on the average 50 μ broad, but often reach 100 μ. They are characterized by the presence in each cell of an axial column of mucilaginous substance which, on the addition of water, bursts through the outer wall in the form of a long tapering cylinder.

2. *The Palisade Cells* are readily seen through the transparent epidermis. Their average breadth is 45 μ, their maximum 90 μ. The double radial walls are 15–20 μ thick, but only about 15 μ high.

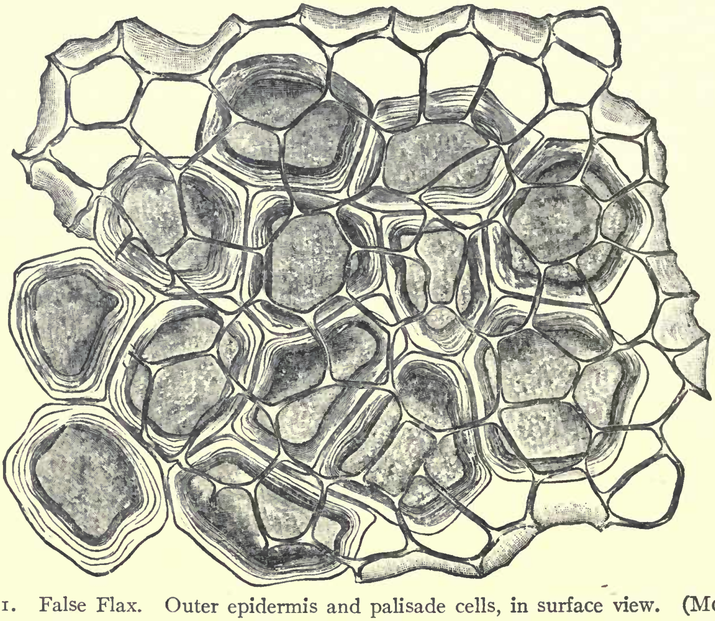


FIG. 151. False Flax. Outer epidermis and palisade cells, in surface view. (MOELLER.)

3. *The Inner Layers* of the spermoderm, corresponding to the pigment cells of allied seeds, consist of compressed cells, which are clearly evident in cross section only after treatment with chloral hydrate.

The Endosperm and Embryo are practically the same as in the mustards, except that the aleurone grains of the embryo seldom exceed 5 μ.

DIAGNOSIS.

Seeds and cake of false flax are identified by the long tapering mucilage column which bursts through the outer epiderims on the addition of water, also by the broad, low palisade cells (Fig. 151).

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Benecke (2); Böhmer (6, 10, 23); Collin et Perrot (9); Hanausek, T. F. (17, 48); Harz (18).

Also see Bibliography of Cruciferæ, p. 176: Gram; Kobus; Sempolowski.

NEVINNY: Die Samen von *Camelina sativa*. Ztschr. Nahr.-Unters. u. Hyg. 1887, **1**, 85.

VAN PESCH: Leindotter-Kuchen. Landw. Vers.-Stat. 1892, **41**, 94.

HEDGE MUSTARD.

Sisymbrium officinale Scop., *S. Sophia* L., and other species of this genus, known as hedge mustard and by other names, are common weeds in both Europe and America.

The brown seeds are minute and more or less irregular in shape.

Gram notes that the epidermis in *S. officinale* contains a mucilaginous substance in layers, with an axial column in each cell which does not readily escape on addition of water, also that the palisade cells are thickened only at the very inner ends.

According to the same author the seeds of *S. Sophia* are very similar to those of shepherd's purse, but the palisade cells are not so broad.

BIBLIOGRAPHY.

See Bibliography of Cruciferæ, p. 176: Böhmer; Gram.

SHEPHERD'S PURSE.

Shepherd's purse (*Capsella Bursa-Pastoris* Moench) has a seed of much the same shape and color as false flax, but of about half the dimensions.

The two seeds are also similar in structure, but in shepherd's purse the mucilage columns seldom burst out of the epidermis, and the palisade cells are not so broad, the average diameter being 30 μ, the maximum 60 μ.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Böhmer (6, 10, 23); also of Cruciferæ, p. 176: Gram.

WILD PEPPERGRASS.

Several species of *Lepidium*, notably *L. campestre* Br. and *L. sativum* L., are common weeds. The small seeds are brown in color and more or less flattened.

In microscopic structure, the species named are characterized by the mucilage column, which, especially after it has burst out of the cell, is broadened at the end. The palisade cells of *L. campestre* are unusually high.

BIBLIOGRAPHY.

See Bibliography of Cruciferæ, p. 176: Böhmer; Gram.

FIELD PENNYCRESS.

According to Böhmer and Gram, the seeds of this common weed (*Thlaspi arvense* L.) frequently occur in linseed and rape cake (Fig. 152).

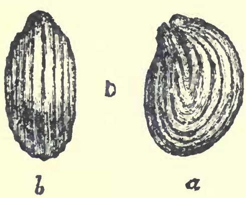


FIG. 152. Field Penny-cress (*Thlaspi arvense*). *a* and *b* seed enlarged; *c* seed natural size. (NOBBE.)

The epidermis and parenchymatous second layer form a membrane of obliterated cells over the palisade layer. In cross section the palisade cells are of unequal height and have strongly thickened inner and side walls. Their appearance in surface view is highly characteristic, owing to the arrangement of the high cells in longitudinal rows forming parallel ribs of a darker color than the intervening channels.

BIBLIOGRAPHY.

See Bibliography of Cruciferæ, p. 176: Böhmer; Gram.

TREACLE MUSTARD.

Seeds of this weed (*Erysimum orientale* R. Br.) occur in rape seed from both Europe and India. They are dull brown, and have a nearly smooth spermoderm.

Gram's figures show the following details:

The epidermal cells contain mucilage which escapes from each as a long conical body. The thickened radial walls are punctured with radially elongated pores, and as a consequence appear toothed in surface view, and scalariform in section. The palisade cells have broad lumens and are seldom thickened except at the inner ends.

BIBLIOGRAPHY.

See Bibliography of Cruciferæ, p. 176: Böhmer; Gram.

WILD RADISH.

Gram finds seeds of the wild radish (*Raphanus Raphanistrum* L.) in small amounts in European rape cake. The seeds are globular, much larger than those of rape, from which they are further distinguished by their red-yellow color. The epidermal and subepidermal cells are broad, and the latter have collenchymatously thickened angles. The palisade cells are rather low, and of unequal height. In surface view they display moderately distinct reticulations. The lumen is usually thicker than the walls.

BIBLIOGRAPHY.

See Bibliography of Cruciferæ, p. 176: Gram.

WINTER CRESS.

The brown-gray, smooth seeds of *Barbarea vulgaris* R. Br., are occasionally present in rape seed.

The mucilage is situated in the outer portion of each epidermal cell, extending inward at the sides. The radial walls are often thickened. In some seeds the subepidermal coat is not evident, in others it consists of one, or seldom two, layers.

Characteristic of the palisade cells are their large size, large lumen, and the single crystal, less often the crystal cluster, present in each.

BIBLIOGRAPHY.

See Bibliography of Cruciferæ, p. 176: Gram.

COMPOSITE OIL FRUITS (*Compositæ*).

The fruits (achenes) of the sunflower, the tarweed (madia), and the niger plant are of local importance. They are characterized by the leathery pericarp, with strongly developed bast-fiber bundles, also by the black pigment plates which cover these bundles. The species are easily distinguished by certain layers of the pericarp and spermoderm described under each.

SUNFLOWER.

Although a native of tropical America, the sunflower (*Helianthus annuus* L.) is grown for its oleaginous seed chiefly in Europe and Asia. In Russia, Hungary, Italy, and India, sunflower oil is used both as a human food and in the arts, and the cake is fed to farm animals. The sunflower is cultivated in other countries chiefly for bird seed or as an ornamental plant.

The obovoid achenes are more or less four-sided and flattened. Although variable in size, they are seldom less than 10 mm. long. In some varieties the pericarp is nearly black, in others, striped with black and white.

HISTOLOGY.

The Pericarp (Fig. 153) is dry and brittle, and may be readily separated from the seed.

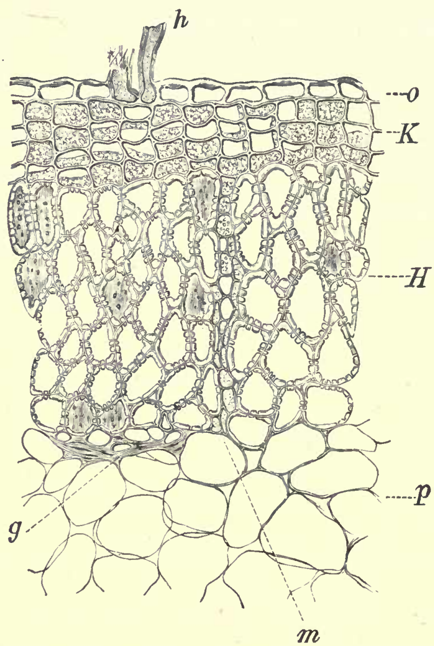


FIG. 153. Sunflower (*Helianthus annuus*). Cross section of outer layers of pericarp. *o* epicarp with *h* hairs; *K* hypoderm; *H* fiber bundles separated by *m* parenchyma; *p* parenchyma with *g* fibro-vascular bundle. ×160. (MOELLER.)

1. *The Epicarp Cells* (Fig. 153, *o*; Fig. 154) are large, usually elongated, with rather thick, porous walls. Stomata are absent. Dark-colored

contents are present throughout in black seeds, but only in some of the cells of striped seeds. Characteristic of this fruit are the broad, thin-walled hairs (*h*), usually in pairs, most of which, however, are broken off in cleaning the seed. As a rule, the members of each pair are united for nearly their entire length. T. F. Hanausek has found that these hairs are attached at their bases to a specially differentiated cell of the epi-

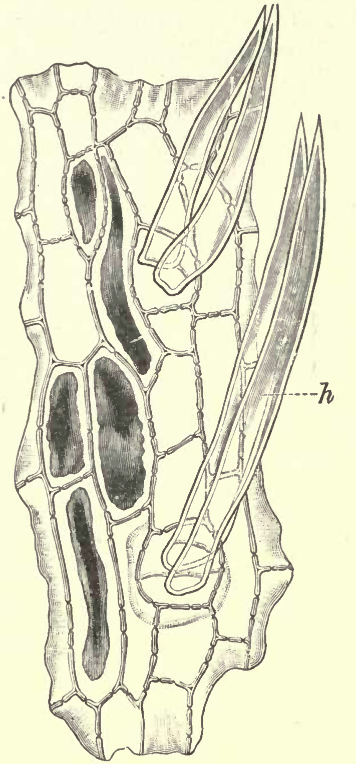


FIG. 154. Sunflower. Epicarp with *h* twin hairs, in surface view. (MOELLER.)

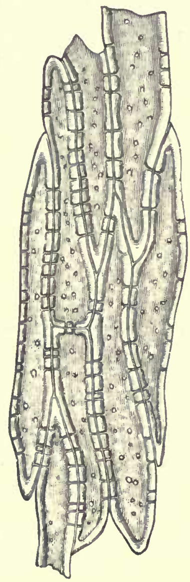


FIG. 155. Sunflower. Fibers of pericarp in surface view. ×160. (MOELLER.)

dermis, known as a "foot cell," one hair being seated directly on this foot cell, the other attached to its side.

2. *Hypoderm* (Fig. 153, *K*; Fig. 155). Three or more layers of cells characterized by their numerous minute pores form this coat. In cross section the cells, like cork cells, are quadrilateral and arranged in radial rows.

3. *Humus Cells.* As is true of madia and niger fruits, the pericarp

of varieties of sunflower with dark or striped seeds, has a deposit of pitch-like substance between the hypoderm and the fiber bundles. Fig. 153 shows a section of a fruit in which this deposit was not present. This material was at one time regarded as an intercellular deposit, but has recently been shown by T. F. Hanausek to consist of a layer of cells, disorganized through what appears to be a humification process. In the early stages of growth the loosely arranged elongated cells bear numerous minute protuberances on the outer and radial walls, which undergo the process of disorganization before the cell proper. This observation led him to surmise that the change was due to oxidation, the air spaces formed by the protuberances facilitating the absorption of oxygen.

4. *The Fiber Bundles* (Fig. 153, *H*; Fig. 155) consist of several layers of longitudinally arranged fibers. Proceeding from without inward, the cells increase in size; the porous walls diminish in thickness. Not only are these bundles larger than in madia and niger, but the elements are broader and have much broader lumens (often 50 μ). The bundles are separated by radial rows of thin-walled cells (Fig. 153, *m*) reminding one of medullary rays, and each adjoins on its inner side a small vascular bundle.

5. *Parenchyma* (*p*). An exceedingly thin-walled, loose parenchyma completes the pericarp. In the ripe seed the cells are much compressed, forming a white, papery tissue.

Spermoderm. A delicate membrane, consisting of spermoderm and endosperm, closely envelops the seed.

1. *The Outer Epidermis* (Fig. 156) as seen in surface view consists of rounded cells about 50 μ in diameter, with rather thick, obscurely beaded walls.

2. *Spongy Parenchyma*, through which ramify the bundles of the raphe and its branches, forms the middle layer.

3. *An Inner Epidermis* of more or less rectangular cells 8–20 μ in diameter, may be seen in section on heating with chloral, and in surface view without treatment with reagents.

Endosperm (Fig. 156). One, sometimes two, layers of typical aleurone cells 15–50 μ in diameter are readily found, both in cross sections and in surface mounts. Rectangular cells predominate, although triangular and polygonal forms also occur.

The Embryo (Fig. 157) consists of two folded cotyledons and a short radicle. The folded cotyledons have several rows of palisade cells adjoining the inner epidermis—the upper epidermis after unfolding. These contain irregularly spherical aleurone grains 3–12 μ in diameter, and fat globules. Only small aleurone grains occur in the epidermal cells.

DIAGNOSIS.

As sunflower achenes are shelled before expressing the oil, the cake contains only such fragments of the pericarp as escape separation. These

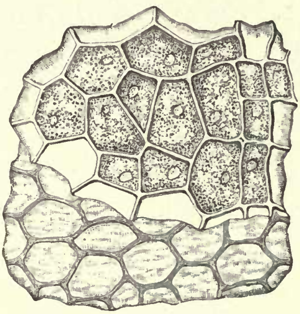


FIG. 156. Sunflower. Outer epidermis of spermoderm (below) and aleurone cells of endosperm (above), in surface view. (MOELLER.)

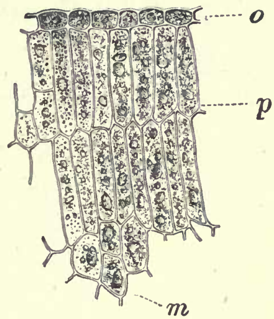


FIG. 157. Sunflower. Cross section of cotyledon. *o* epidermis; *p* palisade cells; *m* isodiametric cells. (MOELLER.)

are readily identified by the twin-hairs (Fig. 154), the cork-like hypoderm with numerous fine pores, and the large fibers (Fig. 155).

The spermoderm, endosperm, and embryo do not possess any characteristic tissues (Figs 156 and 157).

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Benecke (2); Böhmer (6, 10, 23); Collin (8); Hanausek, T. F. (17, 48); Harz (18); Moeller (29).

HANAUSEK, T. F.: Zur Entwicklungsgeschichte des Perikarps von *Helianthus annuus.* Ber. deutsch. Bot. Ges. 1902, **20**, 449.

HEINECK: Beitrag zur Kenntniss des feineren Baues der Fruchtschalen der Compositen. Inaug.-Diss. Giessen. 1890.

KOBUS: Kraftfutter und seiner Verfälschung. Landw. Jahrb. 1884, **13**, 813.

KRAUS: Ueber den Bau der trockner Perikarpien. Inaug.-Diss. Leipzig, 1866, 66.

PFISTER: Oelliefernde Kompositenfrüchte. Landw. Vers.-Stat. 1894, **43**, 441.

MADIA SEED.

Common tarweed, known in Chili as "Madi" (*Madia sativa* Mol.), is one of several species of this genus natives of the Pacific coast of North and South America. It is cultivated as an oil seed in parts of the American continent and more extensively in Germany.

The slender, ribbed achenes, 4–8 mm. long, 2 mm. wide at the apex tapering to the base, are borne in heads 3–6 cm. in diameter. The achenes are usually light in color, but sometimes are nearly black.

HISTOLOGY.

Pericarp (Fig. 158, *F*; Fig. 159). 1. *Epicarp* (*ep*). The cells are longitudinally elongated, variable in size, with colorless, distinctly beaded walls and a thickened cuticle.

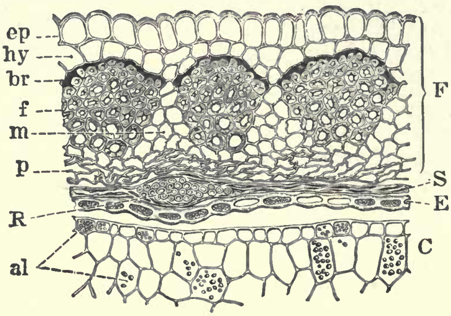


FIG. 158. Madia (*Madia sativa*). Cross section of fruit. *F* pericarp consists of *ep* epicarp, *hy* hypoderm, *br* pigment plates, *f* fiber bundles, *m* partitions, and *p* parenchyma; *S* spermoderm, with *R* raphe; *E* endosperm; *C* cotyledon containing *al* aleurone grains. ×160. (WINTON.)

2. *Hypoderm* (*hy*). Thin-walled more or less collapsed cells form the second layer.

3. *Pigment Plates* (*br*). As in niger seed and some varieties of sunflower, the fiber bundles are covered with dark-colored plates of a material insoluble in all the common reagents, including boiling alkali. In surface view the markings, resembling those of a tortoise shell, which are due to the variable thickness of the pigment material, and the rows of minute pores appearing as light spots in the dark field, make this layer the most striking in the fruit.

4. *Fiber Bundles* (*f*). The fibers are 5–15 μ in diameter and often are 1 mm. long, being smallest in the outer layers. Between the bundles are groups of thin-walled, more or less longitudinally elongated cells, forming wedge-shaped partitions (*m*).

5. *Parenchyma* (*p*). Several rows of partially collapsed parenchyma cells form the inner layers of the pericarp.

The Spermoderm (Figs. 158 and 159, *S*) consists of one distinct layer of parenchyma cells without any striking characters, and other less distinct layers near the raphe bundles.

Curiously shaped, pitted cells (Fig. 159, *sc*), some nearly isodiametric, others greatly elongated, are present at the base of the seed, the longer

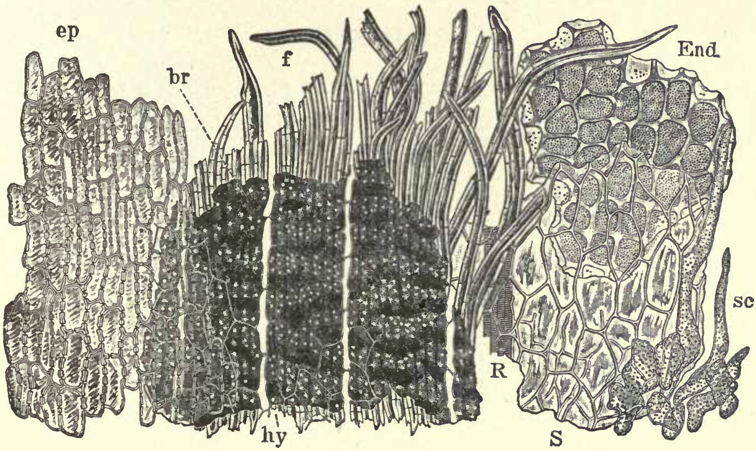


FIG. 159. Madia. Elements of fruit in surface view. *ep* epicarp; *hy* hypoderm; *br* pigment plates; *f* fiber bundle; *S* spermoderm with *R* raphe bundle; *sc* pitted cells at base of spermoderm; *End* endosperm. ×160. (WINTON.)

forms extending in bundles toward the apex. These bundles appear to be distinct from the raphe and its ramifications.

The Endosperm (Figs. 158 and 159, *E*) is represented by a single layer of thick-walled, often quadrilateral, aleurone-cells.

Embryo. Beneath the outer epidermis of the folded cotyledons (Fig. 158, *C*) are several layers of isodiametric cells, but adjoining the inner epidermis are three to four layers of typical palisade cells. Aleurone grains (2–6 μ) and fat are the only visible contents.

DIAGNOSIS.

Madia fruit has much the same structure as sunflower and niger fruits; but is distinguished from the former by having no hairs on the epicarp (Fig. 159, *ep*), a single layer of hypodermal cells, and fibers (*f*) with relatively small diameters; while it differs from niger seeds in having the walls of the epicarp beaded, an inconspicuous hypoderm layer (no rail-shape cells), and the walls of the spermoderm (*S*) straight and non-porous.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Benecke (2); Böhmer (6, 10, 23); Collin (8); Hanausek, T. F. (17, 48); Harz (18).

PFISTER: Oelliefernde Kompositenfrüchte. Landw. Vers.-Stat. 1894, **43**, 441.

WINTON: The Anatomy of Certain Oil Seeds with Especial Reference to the Microscopic Examination of Cattle Foods. Conn. Agr. Exp. Sta. Rep. 1903, 175.

NIGER SEED.

The fruit of *Guizotia Abyssinica* (L) Cass. (*G. oleifera* D.C.), a composite plant, is an important oil seed in Abyssinia, its native country, and also in India. It has been introduced into Europe and America, but has not been extensively cultivated as yet.

The black achenes are shaped like those of madia, but are much smaller, seldom over 5 mm. long and 1 mm. broad at the apex.

HISTOLOGY.

Pericarp (Fig. 160, *F*; Fig. 161). 1. *The Epicarp* cells (*ep*) are distinguished from those of madia by their greater length and the absence of pores.

2. *Hypoderm* (*hy*). Pfister has shown that the isolated, longitudinally elongated cells of this layer are shaped like railway rails, resembling

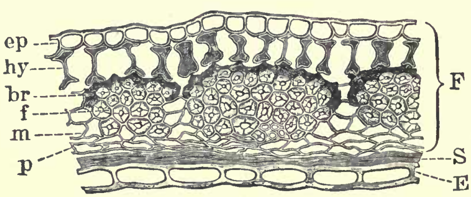


FIG. 160. Niger Seed (*Guizotia Abyssinica*). Cross section of hull. *F* pericarp consists of *ep* epicarp, *hy* hypoderm, *br* pigment plates, *f* fiber bundles, *m* partitions and *p* parenchyma; *S* spermoderm; *E* endosperm. ×300. (WINTON.)

in cross section the hour-glass cells of the legumes. The color of the seed is largely due to the black pigment in this layer.

3. *The Pigment Plates* (*br*) are similar to those of madia seed, but the cross markings are nearer together and not so distinct.

4. *The Fiber Bundles* (*f*) are smaller than the similar bundles of madia, and the individual fibers are narrower.

5. *Parenchyma.* The partitions between the fiber bundles (*m*), and also the inner layers of the pericarp (*p*), consist of parenchyma cells which, in the layers adjoining the spermoderm, are usually compressed.

Spermoderm. 1. *Reticulated Cells* (Figs 160 and 161, *S*). Characteristic of this seed are the reticulated cells with wavy side walls, forming the outer layer of the spermoderm.

2. *Inner Layers.* One or more layers of obliterated cells form the inner spermoderm.

Endosperm (Fig. 160 and 161, *E*). As in madia, the endosperm

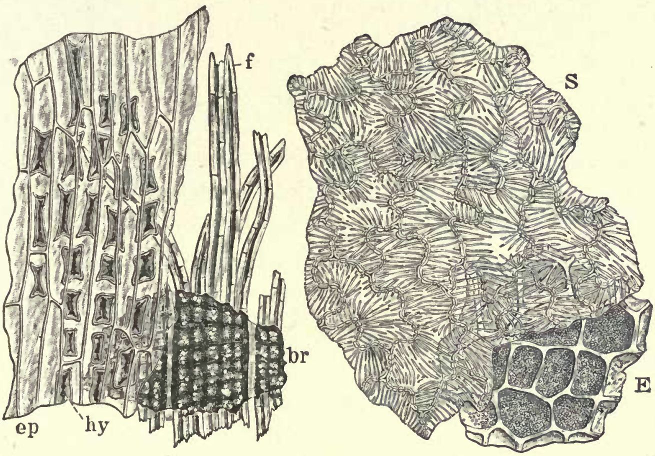


FIG. 161. Niger Seed. Pericarp, spermoderm and endosperm in surface view. *ep* epicarp; *hy* hypoderm; *br* pigment plates; *f* fiber bundle; *S* spermoderm; *E* endosperm. ×300. (WINTON.)

consists of a single layer of thick-walled aleurone cells, often of retangular outline.

Embryo. The thin-walled cells of the embryo contain aleurone grains and fat, and are not distinguishable from those of madia.

DIAGNOSIS.

Niger cake is utilized as a cattle food. The characteristic elements are the rail-shaped cells of the hypoderm (Fig. 161, *hy*) with their dark contents, and the outer layer of the spermoderm (*S*). These are rendered distinct by treatment with alkali.

BIBLIOGRAPHY.

See Bibliography of Madia, p. 200.

MISCELLANEOUS OIL SEEDS.

A number of oil seeds and fruits belonging to widely separated families are of even greater importance for oil production than cruciferous seeds. Of those here described, linseed, cottonseed, castor bean, sesame seed and poppy seed are true seeds, while hemp seed is a dry fruit, and the olive is a fleshy fruit.

LINSEED.

The flax plant (*Linum usitatissimum* L. order *Linaceæ*) is valuable not only for its fibers, but for its seed, which yields one of the most useful of the vegetable oils, also a concentrated cattle food. Since the fiber is in its best condition before the seeds reach maturity, it is not practicable to secure a yield of both fiber and seed from the same crop.

Flax is grown for seed throughout the temperate zone, particularly in India, Russia, Egypt, and the United States.

The anatropous seed is flattened, obovate with a slightly beaked base, and varies from 4–6 mm. in length. To the naked eye the surface is smooth and lustrous, but under a lens appears slightly roughened. The Indian seed is yellow, the ordinary varieties brown. The straight embryo consists of two long, thick cotyledons and a short radicle, the cotyledons being several times as thick as the inclosing endosperm (Fig. 162).

HISTOLOGY.

Sections may be cut dry after embedding the seed in paraffine. They are first treated with ether and alcohol and afterwards mouuted in glycerine, thus preserving the mucilaginous contents of the epicarp cells, and the aleurone grains of the endosperm and cotyledons.

Spermoderm (Fig. 163, *S*; Fig. 164). 1. *The Epidermis* (*ep*) consists of polygonal cells covered by a colorless finely granular cuticle. If sections are first mounted in alcohol, and water is gradually drawn in from one edge, the thick outer wall is seen to have stratified inner layers of a mucilaginous material which nearly fills the cell cavity. It is this mucilaginous substance which gives the seed its value in medicine.

2. *Round Cells* (*p*). One or two layers of yellow cells with circular cavities and marked intercellular spaces form the second layer. Their appearance in surface view is characteristic.

3. *Fiber Layer* (*f*). Strongly thickened, porous fibers longitudinally arranged make up this layer. They vary up to 250 μ in length and 10 μ

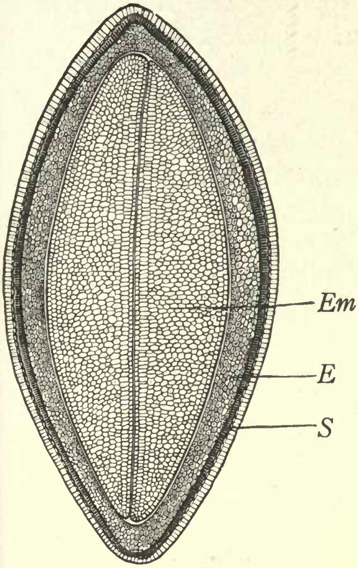


FIG. 162. Linseed (*Linum usitatissimum*). Cross section showing *S* spermoderm, *E* endosperm and *Em* embryo. ×35. (MOELLER.)

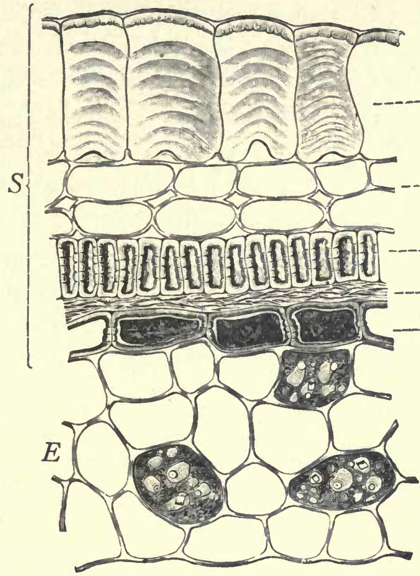


FIG. 163. Linseed. Cross section of *S* spermoderm and *E* endosperm, *ep* outer epidermis; *p* round cells; *f* fiber layers; *tr* cross cells; *g* pigment cells. (MOELLER.)

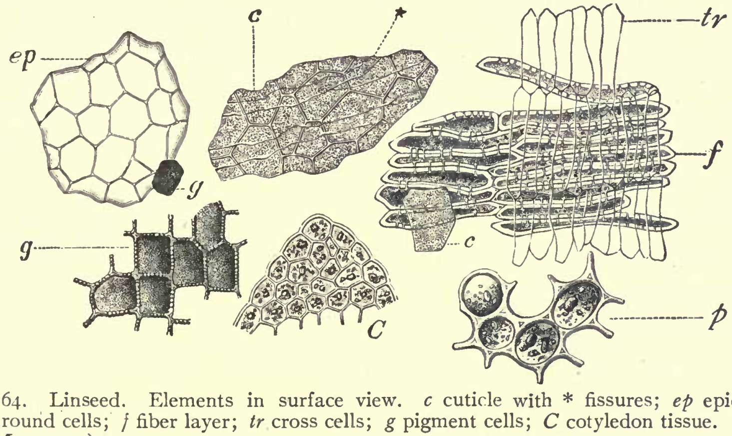


FIG. 164. Linseed. Elements in surface view. *c* cuticle with * fissures; *ep* epidermis; *p* round cells; *f* fiber layer; *tr* cross cells; *g* pigment cells; *C* cotyledon tissue. ×160. (MOELLER.)

in breadth. As may be seen in cross section, their radial diameters are much greater than their breadth.

4. *Cross Cells* (*tr*). Several layers of exceedingly thin-walled, more or less obliterated, colorless cells cross the fibers of the preceding layer at right angles.

Layers 1 to 4 inclusive usually separate from the seed together, presenting in surface view a highly characteristic appearance.

5. *Pigment Layer* (*g*). Equally characteristic are the square or polygonal cells of this layer, with thick, porous walls and yellow or brown contents. This material is insoluble in alcohol or ether, but is colored dark blue by ferric chloride. It separates from the cells in the form of rectangular plates, which, owing to their color, are readily identified.

The Endosperm (Fig. 163, *E*) is usually from 2 to 6 cell layers thick, being thinnest at the edges. The cells have thicker walls than those of the embryo and contain fat and distorted aleurone grains, each grain with a globoid in a sort of beak and an indistinct crystalloid in the body.

Embryo (Fig. 164, *C*). The cells contain large, ovoid aleurone grains up to 20 μ long, like those of the endosperm, also minute grains.

Tschirch and Oesterle recommend mounting in alcohol and running a water solution of iodine under the cover, thus staining the crystalloid yellow.

DIAGNOSIS.

Ground Linseed is used chiefly as a drug, but linseed cake from the oil presses and the ground cake, known as linseed meal, are highly esteemed by cattle feeders.

The conspicuous elements are pieces of the yellow outer spermoderm, consisting of round cells (Fig. 164, *p*), fibers (*f*), and cross cells (*tr*), and also the nearly square, faintly beaded pigment cells (*g*) with brown contents. These tissues are highly characteristic and permit the detection of small amounts of linseed products in mixtures. Starch should not be present in considerable amount.

Linseed Cake and the ground cake known as *Linseed Meal* are often contaminated with cruciferous and other seeds and sometimes adulterated with cheaper products.

The meal is itself used as an adulterant for black pepper and other spices, and as an ingredient of many condimental cattle foods.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Benecke (2); Berg (3); Böhmer (6, 10, 23); Collin (8); Flückiger (11); Hanausek, T. F. (10, 16, 17, 48); Harz (18); Macé (26); Meyer, A. (28); Moeller (29, 30, 31, 32); Schimper (37); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (43, 45).

BERGHE: Tourteaux et Farines de Lin. Bruxelles, 1891.
CRAMER: Ueber das Vorkommen und die Entstehung einiger Pflanzenschleime. Pflanzenphysiologische Untersuchungen von C. Nägali u. C. Cramer, Zurich, 1855.
GODFRIN: Étude histologique sur les tégument séminaux des Angiospermes. Soc. d. Sci. d. Nancy, 1880, 109.
HASELHOFF u. VAN PESCH. Ueber Leinsamenkuchen und Mehl. Landw. Vers.-Stat. 1892, **41**, 55
KOBUS: Kraftfutter und seiner Verfälschung. Landw. Jahrb. 1884, **13**, 813.
KOŘAN: Der Austritt des Schleimes aus dem Leinsamen. Pharm. Post, 1899, **32**.
SEMPOLOWSKI: Ueber den Bau der Schale landwirthschaftlich wichtiger Samen. Landw. Jahrb. 1874, **3**, 823.

COTTON SEED.

The varieties of upland or short-staple cotton commonly cultivated for fiber are classed under *Gossypium herbaceum* L. (order *Malvaceæ*),

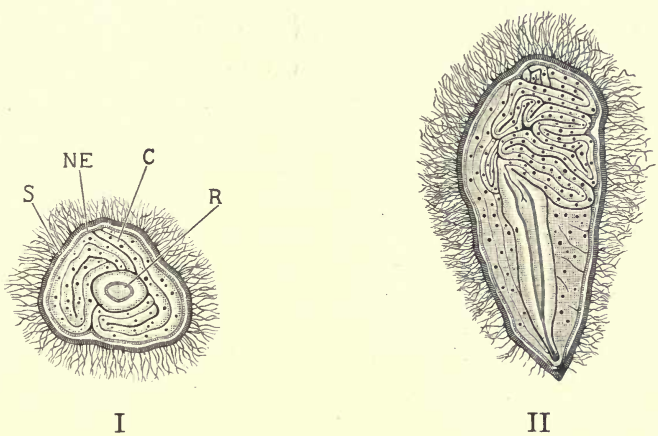


FIG. 165. Cotton Seed (*Gossypium herbaceum*). *I* transverse section. *II* longitudinal section. *S* spermoderm; *NE* perisperm and endosperm; *C* cotyledons; *R* radicle. ×4. (WINTON.)

although quite probably some of these varieties have been obtained by crossing with other species. Other species of economic importance are Sea Island or long-staple cotton (*G. barbadense* L.), and tree cotton (*G. arboreum* L.).

The culture of cotton has extended from India, its native country, to northern Africa, the southern states of the United States, Brazil, and other warm regions.

Within the bolls are borne numerous seeds in a mass of fibers, the latter being but epidermal cells of the spermoderm prolonged as hairs (Fig. 165). After ginning, the seeds of upland cotton are still enveloped by a close ground fiber, often gray or green in color, which cannot be easily removed. Sea Island cotton seed is nearly free from ground fiber. Freed from the fiber, the pointed, egg-shaped, black or dark-brown seed is 6–12 mm. long. The chalaza is a little to one side of the broad upper end, the hilum and micropyle at the pointed lower end, the raphe connecting them being evident as a ridge on the surface. A shell-like spermoderm and a thin skin consisting of perisperm and endosperm inclose the bulky embryo, the latter having cotyledons which in cross section are dotted with minute dark-brown resin cavities.

HISTOLOGY.

The Spermoderm (Fig. 166, *S*; Fig. 167) is 300 μ thick, separating readily from the seed. The inner surface is brown with a whitish opalescence.

1. *Epidermis* (*ep*). Over the raphe the epidermis is 30–40 μ thick, but in other parts it seldom exceeds 25 μ. The cells are conspicuous because of the thick (5–12 μ), stratified, yellow walls and the dark-brown contents. In surface view, the cells are irregular in shape and vary in size from less than 10 to over 60 μ. About the hairs they form rosettes. The hairs of cotton are twisted, thus distinguishing them from all other textile fibers. Stomata with thin, colorless-walled guard cells occur either singly or in pairs.

2. *Outer Brown Coat* (*br*). The hypodermal coat consists of thin-walled, often compressed cells, with indistinct contour and brown contents. Over most of the surface, this coat is but 20–40 μ thick, and consists of only two or three cell layers, but about the raphe it is several times thicker.

3. *Colorless Cells* (*w*). The next layer consists of small (10–30 μ), colorless cells, with sharply defined walls 2–3 μ thick. Cells divided by tangential partitions occur not infrequently. Hanausek states that these cells contain occasional oxalate crystals or granular masses; most of them, however, are empty.

4. *Palisade Cells* (*pal*). Over one-half of the thickness of the spermoderm is due to the thickened palisade cells. These remarkable and exceedingly characteristic cells are 8–20 μ wide, and about 150 μ long, each consisting of an outer portion of about one-third the length of the cell with nearly colorless walls, and an inner portion

with yellowish-brown walls. The lumen in the outer portion of each cell is narrow except for a globular enlargement at the inner end, 4–6 μ in diameter, containing a dark-colored material. Seen in tangential section, this cavity has radiating branches. An indistinct light line adjoins

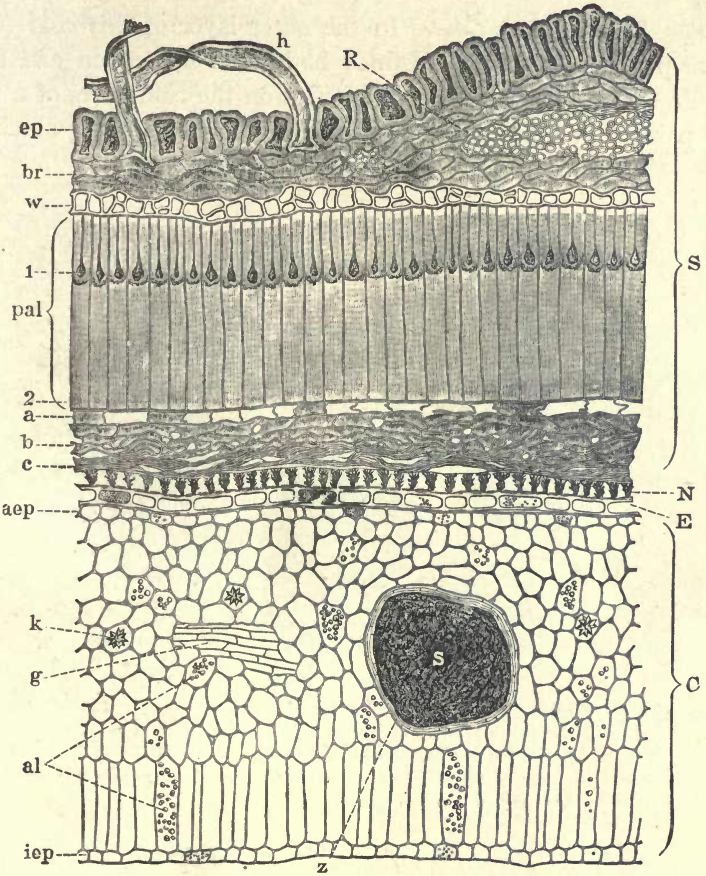


FIG. 166. Cotton Seed. Cross section. *S* spermoderm consists of *ep* epidermis with *h* hair, *br* outer brown coat with *R* raphe, *w* colorless cells, *pal* palisade cells, and *a*, *b* and *c* layers of inner brown coat; *N* perisperm; *E* endosperm; *C* cotyledon with *aep* outer epidermis and *iep* inner epidermis; *s* resin cavity surrounded by *z* mucilage cells; *al* aleurone grains; *k* crystal cells; *g* procambium bundles. ×160. (WINTON.)

the outer wall. No lumen at all appears in the inner portion of these cells in cross section, but in tangential section faint radiating lines are evident, due, according to von Bretfeld, to *lamellæ* arranged about the axis of the cell. Individual cells isolated by macerating with Schulze's solution and treated with chromic acid show clearly this differentiation.

The same author found that the outer portion has all the chemical and optical properties of pure cellulose, the inner portion, those of lignified cellulose. Cross sections viewed with polarized light exhibit with a dark field a beautiful play of color in the outer, a clear white light in the inner portion.

5. *The Inner Brown Coat.* In the outer layer of this coat (*a*), the cells are polygonal, and well defined both in cross section and surface view. Proceeding inward, the tissue takes on the characters of a typical spongy parenchyma, the cells in the innermost layers being much com-

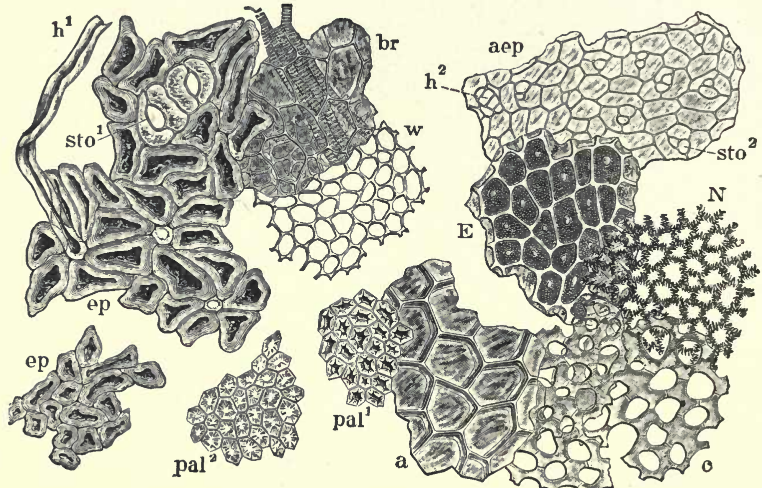


FIG. 167. Cotton Seed. Surface view of outer layers. *ep* epidermis of spermoderm with h^1 hair and sto^1 stoma; *br* outer brown cells; *w* colorless cells; pal^1 and pal^2 palisade cells (see Fig. 166); *a*, *b*, *c* layers of inner brown coat of spermoderm; *N* perisperm; *E* endosperm; *aep* outer epidermis of cotyledon with h^2 multicellular hair and sto^2 stoma. ×160. (WINTON.)

pressed (*b* and *c*). Brown coloring matter like that in the second layer of the spermoderm is usually present only in the cells of the outer layers. Owing to the absence of cell-contents in the inner obliterated cells, the inner surface of the spermoderm is more or less opalescent.

Perisperm (Figs. 166 and 167, *N*). An exceedingly thin skin consisting of a single cell layer of perisperm and another of endosperm covers the embryo. The colorless perisperm cells are characterized by the fringe-like walls made up of threads perpendicular to the surface. Hanausek's name, "fringe cells," is very appropriate.

Endosperm (Figs. 166 and 167, *E*). A single layer of moderately thick-walled cells containing small aleurone grains constitutes the endosperm.

Embryo. After soaking for a day in water, the complicated folds of the cotyledons (Fig. 166, *C*) may be straightened out and their broad kidney shape noted.

By scraping the cotyledons the epidermis (Figs. 166 and 167, *aep*) may be removed for examination. As was first noted by Hanausek, three kinds of cells are present: first, thin-walled polygonal cells; second, pairs of cells with curved walls, the guard cells of incipient stomata (sto^2); and third, small cells continued beyond the surface in the form of oval hairs divided into several cells by cross partitions (h^2). The hairs are most abundant at the point of insertion on the axis.

Sections of the cotyledons and radicle may be cut dry without removing the spermoderm, although better sections are obtained after removing the spermoderm and embedding directly in paraffine.

In the outer portion of the mesophyl, the cells are isodiametric, in the inner layers, of typical palisade form. Procambium bundles (*g*) run longitudinally or obliquely through the mesophyl.

Crystal clusters (*k*) occur in cells scattered here and there, but in most of the mesophyl cells aleurone grains and fat are the only visible contents. The aleurone grains (*al*) are 2–5 μ in diameter and are more or less angular or irregular in shape. Alkali dissolves the aleurone grains and other contents and imparts a deep-yellow color to the tissues.

The so-called resin cavities of the cotyledons (*s*), containing a dark-colored secretion, appear to the naked eye as brown dots in the nearly colorless ground tissue. Around these cavities two or more indistinct rows of exceedingly thin, elongated cells (the mucilage cells of Hanausek) are arranged in concentric layers.

We are indebted to Hanausek for the following observations: Examined in water, the secretion is olive-green, flowing out of the cavities in the form of a yellow-green emulsion, the particles of which are in lively motion. Strong sulphuric acid dissolves the secretion to a beautiful blood-red solution. Alkalies color it green-brown, but do not dissolve it.

DIAGNOSIS.

Undecorticated Cottonseed Cake. It is customary in India, Egypt, and in most cotton-growing countries, except the United States, to express the oil without previous removal of the hulls. The cake obtained as a by-product in this process, although containing more fiber and less protein than the decorticated cake, is preferred by the English feeders, because of the mechanical action of the hulls.

Samples should be mounted in water and examined first directly to detect possible starchy adulterants, and again after addition of alkali, noting the fragments of spermoderm and the yellow color of the disorganized lumps. The coats of the spermoderm are best studied in fat- and protein-free material obtained by the crude-fiber process or by Hebebrand's method (p. 172).

Especially characteristic are the thick-walled epidermal cells (Figs. 166 and 167, *ep*) with hairs and the palisade cells (*pal*), although the other layers aid in identification. The fringe cells (*N*) of the perisperm are characteristic, but not so conspicuous as are the layers of the spermoderm.

The cake or meal from common cotton contains more fiber (often attached to fragments of hull) and less abundant brown pigment in both the outer brown layer and the inner, than products of the varieties of *G. Barbadense* (Sea Island Cotton, Egyptian Cotton, etc.). Voelcker places considerable dependence on the more or less pronounced opalescent appearance of the inner surface of the hulls of Bombay seed as distinguished from the deep-brown inner surface of the hulls from Egyptian seed, a distinction which also holds good in most cases between upland and Sea Island seed as grown in the United States. This observation, first brought to notice by Richardson of Lincoln, England, depends on the degree of obliteration of the innermost cells of the spermoderm.

Decorticated Cotton-seed Cake. In the United States, upland cotton seed is hulled before expressing the oil, the cake and the rich yellow meal obtained by grinding the cake consisting of material from the cotyledon with only a small amount of spermoderm. This meal is often grossly adulterated with ground cotton hulls, and occasionally with rice refuse. Finely ground hulls, owing partly to the fine state of division of the dark-colored matter, and partly to the exposure of the nearly colorless palisade cells, is not so dark as the coarsely ground hulls and more readily escapes detection in the meal.

Determinations of nitrogen and fiber, coupled with microscopic examination of the original material and of the crude fiber, serve for the detection of this form of adulteration.

Cotton Hulls formerly were burned as a fuel under the boilers of the oil mills, and the ash, rich in potash, utilized as a tobacco fertilizer. They are now used for feeding cattle or as an adulterant of cotton-seed meal, as noted above.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Benecke (2); Böhmer (6, 10, 23); Collin (8); Hanausek, T. F. (17, 48).

v. BRETFELD: Anatomie des Baumwolle- und Kapoksames. Jour. f. Landw. 1887, **35**, 29.

HANAUSEK, T. F.: Zur mikroskopischen Charakteristik der Baumwollsamen-Producte. Ztsch. allg. österr. Apoth.-Ver. 1888, **26**, 569, 591.

KOBUS: Kraftfutter und seiner Verfälschung. Landw. Jahrb. 1884, **13**, 813.

VOELCKER: Methods of Discriminating between Egyptian and Bombay Cotton Seed Cakes. Analyst. 1903, **28**, 261.

WINTON: The Microscopic Examination of American Cotton Seed Cake. Analyst. 1904, **29**, 44. The Anatomy of Certain Oil Seeds with Especial Reference to the Microscopic Examination of Cattle Foods. Conn. Agr. Exp. Sta. Rep. 1903, 175.

KAPOK SEED.

Several tropical trees belonging to the order *Bombaceæ* have capsules filled with a dense mat of woolly hairs which spring from the endocarp, not as in the case of the cotton, a member of a closely related family, from the spermoderm. These hairs are too brittle to be of value as textile fibers, but are used for upholstery. Of these "silk-cotton trees" the kapok (*Ceibo pentandra* (L.) Gärtn., *Eriodendron anfractuosum* DC.), growing in the East and West Indies and other tropical regions, is of importance, not only for the fibers but also for the oily seeds, which resemble cotton seeds in structure. In the Celebes the seeds are eaten by the natives, and in various countries are used for making oil. Two German authors, Reinders and Kobus, state that the cake is an adulterant of linseed cake.

The campylotropous seed is about the size of a pea and has a swollen funiculus which covers the chalaza. The cotyledons are folded similarly to those of the cottonseed, but do not have resin cavities.

HISTOLOGY.

The following comparison of the structure of cotton and kapok seeds is given by v. Bretfeld:

	COTTON SEED.	KAPOK SEED.
Spermoderm.		
1. Epidermis:	sclerenchymatized with hairs;	thin-walled with gland-like cavities.
2. Outer Brown Coat:	with fibro-vascular bundles;	without fibro-vascular bundles.

	Cotton Seed.	Kapok Seed.
Spermoderm:		
3. Colorless Cells:	1–2 cell layers;	3–4 cell layers with crystal clusters.
4. Palisade Cells:	⅓ longer;	⅓ shorter.
5. Inner Brown Coat:	more star cells;	fewer star cells.
Perisperm:	cells smaller, walls more knotty;	cells larger, walls less knotty.
Cotyledons:	green tissue with resin cavities;	colorless tissue without resin cavities.

BIBLIOGRAPHY.

Bretfeld: Anatomie des Baumwolle- und Kapoksamens. Jour. Landw. 1887, **35**, 29.
Kobus: Kraftfutter und seiner Verfälschung. Landw. Jahrb. 1884, **3**, 813.
Van Pesch: Kapok-Kuchen. Landw. Vers.-Stat. 1896, **47**, 471.

HEMP-SEED.

Hemp (*Cannabis sativa* L. order *Cannabineæ*) is grown as a fiber plant throughout Europe, especially in Russia, also in Africa, India, China, Brazil, the United States and other regions.

When the production of fiber alone is considered, the plant is cut shortly after blooming; but in Russia it is allowed to grow until the fruit reaches maturity, thus securing a yield of seed as well as fiber. Indian hemp (*Cannabis sativa* var. *Indica*) is grown exclusively as a medicinal herb.

The diœcious plant yields an oval, somewhat flattened, two-ribbed fruit, consisting of a brown pericarp delicately marked with white veins (Fig. 168, *II* and *III*, *F*), a spermoderm (*S*) of a green color, a thin endosperm, and a bulky embryo with thick cotyledons (*C*) and a radicle (*R*) bent parallel to the cotyledons. The "seeds" on the market consist, for the most part, of naked fruit, with an occasional fruit inclosed within the hooded calyx (Fig. 168, *I*).

HISTOLOGY.

Calyx (Fig. 169). 1. *Outer Epidermis* (*aep*). From among the polygonal cells of the epidermis arise two very characteristic and striking elements: first, the glands, either sessile or stalked (*d*); and second, the cystolith hairs (*h*). The glands are globular with eight or more cells on the under side radiating, usually, from two central cells, the secretion cavity being formed by the separation of the outer cuticle from these cells. These glands are usually borne on many-celled stalks, often 300 μ long. The cystolith hairs are characterized by their irregularly globular bases, often 75 μ in diameter, in which is suspended a cystolith of calcium carbonate (*cy*). They taper either abruptly or gradu-

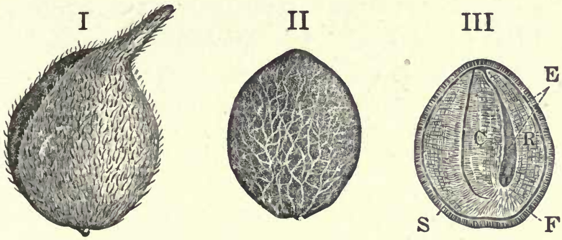


FIG. 168. Hemp (*Cannabis sativa*). *I* calyx. *II* outer surface of fruit. *III* longitudinal section of fruit. *F* pericarp; *S* spermoderm; *E* endosperm; *C* cotyledon; *R* radicle. ×4. (WINTON.)

ally from this base to the pointed apex, in the latter case often reaching a length of 500 μ and sometimes 1 mm. The walls, although but one-half to one-sixth as thick as the lumen, are often 8 μ thick.

2. *Mesophyl* (*mes*). Several layers of small cells, through which run numerous bundles, make up the mesophyl. In the inner layer the

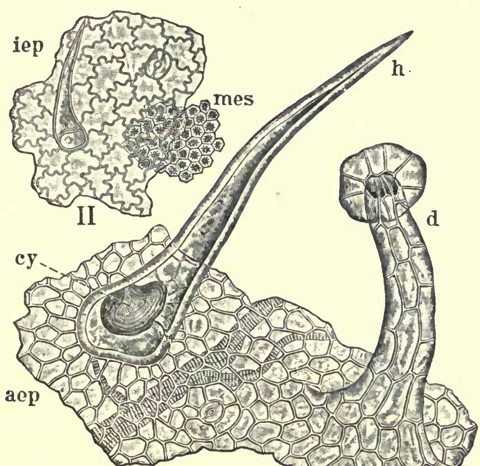


FIG. 169. Hemp. Calyx in surface view. *aep* outer epidermis with *h* hair containing *cy* cystolith, and *d* glandular hair; *mes* mesophyl containing crystals; *iep* inner epidermis. ×160. (WINTON.)

cells are about 10 μ in diameter and contain crystal clusters of calcium oxalate.

3. *The Inner Epidermis* (*iep*). Cells with wavy outline, thin-walled hairs, and stomata form the inner layer.

Pericarp (Figs. 170 and 171). 1. *Epicarp* (*ep*). This layer consists of more or less sclerenchymatized cells with wavy outline. The radial walls are, in some parts, moderately thickened, in others so thick that there is but a narrow lumen. All the walls are porous.

2. *Spongy Parenchyma* (*hy*). One or more layers of colorless cells, usually with numerous circular intercellular spaces, form a hypodermal

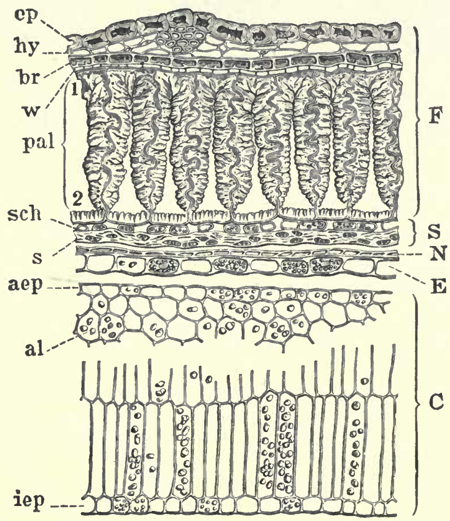


FIG. 170. Hemp Seed. Cross section of fruit. *F* pericarp consists of *ep* epicarp, *hy* hypoderm, *br* brown cells, *w* dwarf cells, and *pal* palisade cells; *S* spermoderm consists of *sch* tube cells and *s* spongy parenchyma; *N* perisperm; *E* endosperm; *C* cotyledon with *aep* outer epidermis, and *iep* inner epidermis; *al* aleurone grains. ×160. (WINTON.)

coat. Through this layer run the numerous anastomosing bundles, which, seen through the epicarp, are evident to the naked eye as veins. This layer is thickest in the two keels of the fruit.

3. *Brown Cells* (*br*). Owing to their greater thickness and the presence of brown contents, these cells are more readily distinguished in cross section than those of the preceding layer. In preparations obtained by heating the fruit in alkali and scraping, they are conspicuous. Focusing on the outer wall, the radial walls are straight or moderately sinuous; but further inward they are zigzag with projections—often branching—extending into the cell cavity and forming in each cell what appear to be several indistinct compartments. The cell-contents, after this treatment, form irregular lumps shrunken away from the walls.

4. *Dwarf Cells* (*w*). Owing to its thinness, this layer can be seen in cross section only in carefully cut specimens; but in tangential sections

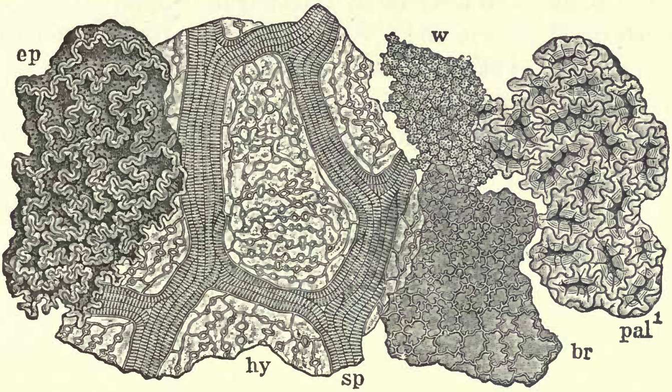


FIG. 171. Hemp. Pericarp in surface view seen from without. *ep* epicarp; *hy* hypoderm with *sp* spiral vessels; *br* brown cells; *w* colorless cells; *pal*[1] palisade cells (see Fig. 170). ×160. (WINTON.)

or preparations obtained by the treatment above described, the minute, colorless, porous cells (seldom over 12 μ) with wavy, radial walls are readily distinguished.

5. *Palisade Layer* (*pal*). This layer, owing to its thickness (often 100 μ), the peculiarly thickened porous walls, and the wavy outlines of

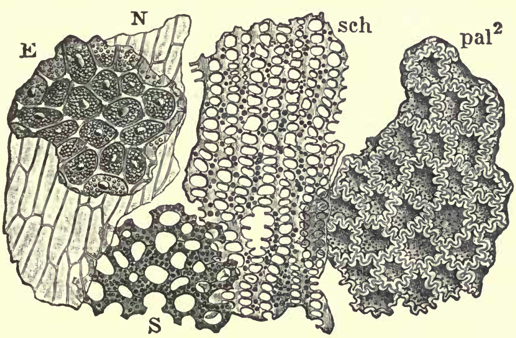


FIG. 172. Hemp. Palisade cells, spermoderm, perisperm, and endosperm seen from within. *pal*[2] palisade cells (see Fig. 170); *sch* tube cells and *S* spongy parenchyma of spermoderm; *N* perisperm; *E* endosperm. ×160. (WINTON.)

the radial walls as seen both in cross and tangential sections, is the most conspicuous and characteristic of all the layers of the fruit. So strongly sclerenchymatized are the outer and, except at the inner end, the radial walls, that the lumen is reduced to a narrow line for fully two-thirds of the outer portion of the cell (*pal*[1]); at the inner wall, however, the radial walls abruptly narrow, leaving a wide lumen (Fig. 172, *pal*[2]). The inner wall is porous and moderately thickened.

Spermoderm (Figs. 170 and 172, *S*). The cells contain green granules, which are insoluble in alcohol, ether, and alkali.

1. *Tube Cells* (*sch*). The outer layer is quite distinct from the inner layer, owing to the elongated form of the cells and the elongated rows of intercellular spaces.

2. *Inner Layer* (*s*). Further inward the cells form an indistinct spongy parenchyma with star-shaped or irregular cell outlines.

Perisperm (Figs. 170 and 172, *N*). If the fruit is soaked for a day or two in $1\frac{1}{4}$ per cent soda solution, the perisperm with adhering endosperm readily separates from the spermoderm on the one hand and the embryo on the other. In cross section it is indistinctly seen.

The Endosperm (Figs. 170 and 172, *E*) forms a coat, mostly one cell-layer thick, about the whole embryo, and also extends in the form of a partition several layers thick between the cotyledons and the radicle. These cells, containing small protein grains, resemble the aleurone cells of the cereals.

Embryo (Fig. 170, *C*). Both epidermal layers of the cotyledons are composed of small cells with aleurone grains 2–3 μ in diameter. Beneath the outer epidermis are several layers of isodiametric cells, while adjoining the inner epidermis are two layers of typical palisade cells. Both forms of cells contain, in addition to fat, aleurone grains up to 8 μ. Each grain consists of an irregularly-spherical or elliptical body containing a crystalloid with a globoid excrescence.

DIAGNOSIS.

The seeds serve primarily for the production of oil; but the cake from the oil presses is utilized in various parts of Europe as a cattle food, a fertilizer, and possibly as an adulterant.

The characteristic elements are the epicarp (Fig. 171, *ep*), the spongy parenchyma (*hy*) with anastomosing bundles, the dwarf cells (*w*), the palisade cells (*pal*), and the tube cells (Fig, 172, *sch*) of the spermoderm with green contents insoluble in alcohol, ether and alkali.

Extraction with ether, and treatment by Hebebrand's method (p. 172) may be used to prepare material for examination. If sufficiently large fragments of the shell are obtainable, the palisade cells are best identified in cross section, and the dwarf cells in tangential section. The aleurone grains, if still intact, may be seen in turpentine mounts.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Benecke (2); Böhmer (6, 10, 23); Collin (8); Hanausek, T. F. (17); Harz (18); Tschirch (39); Tschirch u. Oesterle (40).

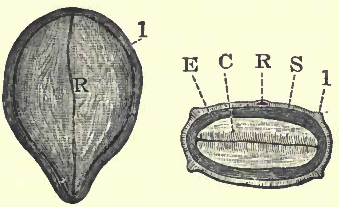
MACCHIATI: Sessualità, anatomia del frutto e germinatione del seme della canapa. Bull. d. Statione agraria di Modena, 1889, Nov. Ser. **9**.

TSCHIRCH: Ueber den anatomischen Bau und die Entwickelungsgeschichte der Secretdrüsen des Hanfes. Naturforscherversammlung, 1886. Ber. in Pharm. Ztg, 1886, **31**, 577.

WINTON: Anatomie des Hanfsamens. Ztschr. Unters. Nahr.-Genussm. 1904, **7**, 385. The Anatomy of Certain Oil Seeds with Especial Reference to the Microscopic Examination of Cattle Foods. Conn. Agr. Exp. Sta. Rep. 1903, 175.

SESAME SEED.

Common sesame (*Sesamum Indicum* L., order *Gesneraceæ*) is one of the most valuable cultivated plants in India, China, Asia Minor, Palestine, Arabia, and other parts of the Orient, the seeds serving for the production of oil and cake, also for direct consumption as human food. The plant is also to some extent cultivated in Egypt, parts of East Africa, and in the warmer parts of North and South America.



I II

FIG. 173. Sesame Seed (*Sesamum Indicum*). *I* outer surface of seed. *II* transverse section. *S* spermoderm with *l* ridges and *R* raphe; *E* endosperm; *C* cotyledon. ×8. (WINTON)

The flattened pear-shaped seeds (Fig. 173) are 2–3 mm. long and vary in color from white to brown. Passing longitudinally through the center of one of the flattened sides, is the raphe (*R*), and running around the edge of each of the flattened surfaces is an indistinct ridge conforming to the shape of the seed (*l*). The endosperm (*E*) is about half as thick as the cotyledon (*C*).

HISTOLOGY.

Spermoderm (Fig. 174, *S*; Fig. 175). 1. *Epidermis* (*ep*). The cells throughout are radially elongated with convex outer walls. Owing to the thinness of the radial walls, they are usually collapsed, but assume their normal form on heating cross sections with dilute alkali. The cells forming the ridges are empty and, as was first noted by Benecke, are arranged like the vanes of a feather. In other parts the cells are parallel and each contains in the extreme outer end, adjoining the thin outer wall,

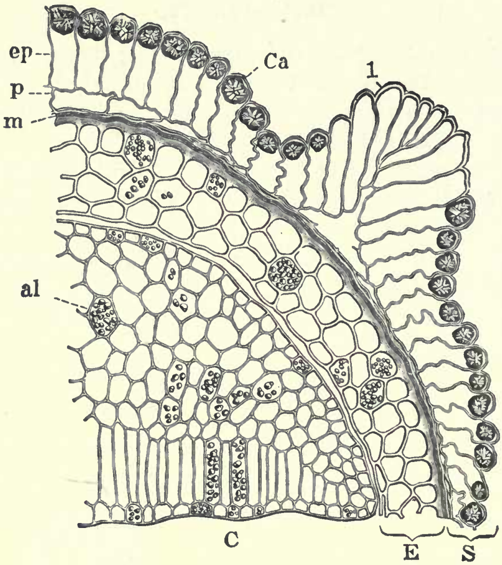


FIG. 174. Sesame. Cross section of seed. *S* spermoderm consists of *ep* epidermal cells with *Ca* crystal masses, *l* epidermal cells of ridges, *p* parenchyma and *m* yellow membrane; *E* endosperm; *C* cotyledon containing *al* aleurone grains. ×160. (WINTON.)

an irregularly spherical mass consisting of calcium oxalate crystals (*Ca*), apparently within a thin membrane. These masses are 12–40 μ in diameter. In surface view, as may be clearly seen by examination of the skin which separates after boiling the seed in water, the crystal cells are isodiametric-polygonal (*ep*), the cells of the ridges slightly elongated (*l*).

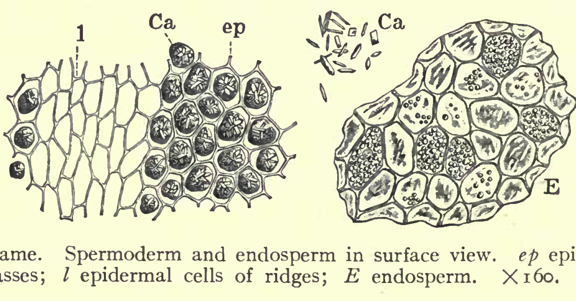


FIG. 175. Sesame. Spermoderm and endosperm in surface view. *ep* epidermis with *Ca* crystal masses; *l* epidermal cells of ridges; *E* endosperm. ×160. (WINTON.)

By boiling with alkali on the slide, some of the epidermal cells may be isolated and, after staining with chlorzinc iodine, viewed in a horizontal position. Sometimes the crystal masses are disintegrated, the separate crystals presenting the appearance shown in Fig. 175.

2. *Parenchyma* (Nutritive Layer) (*p*). One, sometimes more, layers of collapsed cells, form what in the earlier stages of growth was a nutritive layer. Only after heating with alkali is the cellular structure at all evident in cross section and then but indistinctly. After removing the epidermis as above described and treating the seed with safranin or chlor-zinc iodine, colored fragments may be removed from the surface of the seed, which often show longitudinally elongated cells. Hanausek has noted that the cells contain loose crystals of calcium oxalate.

3. *Yellow Membrane* (Fig. 174, *m*). Lining the inner surface of the spermoderm is a membrane, probably the cuticle of an obliterated inner epidermis.

Endosperm (Figs. 174 and 175, *E*). The outer wall of the endosperm is strongly thickened. At the ends of the elliptical cross sections there are but two cell layers, but on the sides there are three to five layers. The cells contain aleurone grains (2–6 μ), and fat.

Embryo (Fig. 174, *C*). The cells of the cotyledons, except in the single layer of palisade cells, are isodiametric and like those of the endosperm, contain aleurone grains (up to 10 μ) and fat, but no starch. Hanausek states that each grain contains either a crystalloid or, at one of the poles, a globoid.

DIAGNOSIS.

Not only is sesame oil one of the most valuable of the vegetable oils, but the seed itself is an ingredient of various articles of diet throughout the warmer countries of the East, and the cake obtained as a by-product in the manufacture of the oil serves as food for both man and beast. Sesame cake has been imported into Europe in large amount, where it is highly esteemed by cattle feeders.

Samples of sesame cake may be prepared for examination by Benecke's or Hebebrand's method or by simply boiling with $1\frac{1}{4}$ per cent alkali. Previous extraction with ether is desirable.

Characteristic of common sesame are radially elongated, thin-walled epidermal cells (Fig. 175, *ep*), each with a crystal mass (*Ca*) in the outer end. In black sesame (*S. radiatum* S. et T.) the masses are in the inner end of the cell, where the cell-wall is strongly thickened.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Benecke (2); Böhmer (6, 10, 23); Collin (8); Hanausek, T. F. (17, 48); Harz (18).

BENECKE: Die verschiedenen Sesamarten und Sesamkuchen des Handels. Pharm. Centralh. 1887, 545.
HEBEBRAND: Ueber den Sesam. Landw. Vers.-Stat. 1898, **51**, 45.
KOBUS: Kraftfutter und seiner Verfälschung. Landw. Jahrb. 1884, **13**, 813.
WINTON: The Anatomy of Certain Oil Seeds with Especial Reference to the Microscopic Examination of Cattle Foods. Conn. Agr. Exp. Sta. Rep. 1903, 175.

CASTOR BEAN.

The castor-bean plant (*Ricinus communis* L., order *Euphorbiaceæ*) is grown for its oily seeds, from which is obtained the castor-oil of commerce. Castor pomace, although not suited for use as a cattle food because of the highly poisonous ingredient "ricine," is a valuable fertilizer. As this material has repeatedly been consumed by animals with fatal results, its microscopic detection is sometimes desirable.

The seeds are obovoid, slightly flattened, with markings like those of a tortoise shell. On one of the flattened sides the raphe is clearly evident, and at the base a prominent caruncle. The spermoderm is hard and exceedingly brittle; the endosperm is bulky; the cotyledons of the axial embryo are broad but thin.

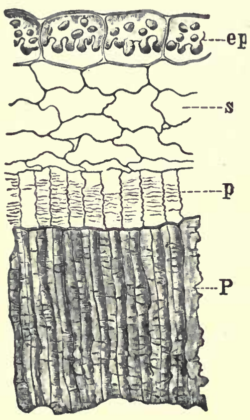


FIG. 176. Castor Bean (*Ricinus communis*). Cross section of outer portion of spermoderm. *ep* epidermis; *s* spongy parenchyma; *p* thin-walled palisade cells; *P* sclerenchymatized palisade cells. (MOELLER.)

HISTOLOGY.

The Spermoderm (Fig. 176) consists of five distinct layers of which four are readily removed as a brittle shell. As noted by Collin, the three outer layers may be separated from the fourth by boiling with dilute alkali. The innermost layer remains attached to the seed after shelling.

1. *The Epidermis* (Fig. 176, *ep;* Fig. 177) is characterized by the sharply polygonal, finely pitted cells, some of which are colorless, others of a brown color, hence the mottled appearance of the seed.

2. *Spongy Parenchyma* (*s*) forms a layer several cells thick.

3. *Thin-walled Palisade Cells* (*p*) with dark contents are the elements of the third layer. In surface view the cells are polygonal or rounded, 12–20 μ in diameter, and often have intercellular spaces at the angles.

4. *Sclerenchymatized Palisade Cells* (*P*) constitute a layer 200 μ thick. The cell-walls are of a brown color and show distinct pores. At the

outer ends the cell cavities are somewhat broader than at other parts. Seen in surface view, the cells are polygonal, 8–15 μ in diameter.

5. *Inner Layer.* After removing the foregoing layers, the seed, on close examination, is seen to be enveloped by a thin white skin—the inner layer of the spermoderm. This consists of a colorless, thin-walled, more or less compressed parenchyma, several cells thick, and numerous fibro-

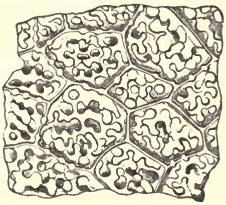


FIG. 177. Castor Bean. Outer epidermis in surface view. (MOELLER.)

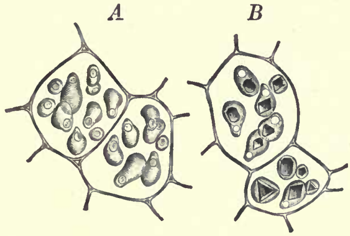


FIG. 178. Castor Bean. Aleurone grains of endosperm. *A* in oil; *B* in iodine solution. (MOELLER.)

vascular bundles. Crystal clusters and radiating groups of feather-like crystals are readily found in surface mounts.

Endosperm (Fig. 178). By far the greater part of the reserve material of the seed, consisting largely of aleurone grains and fat, is in the endosperm. The aleurone grains are round, ellipsoidal, or egg-shaped, and frequently reach a diameter of 20 μ. Each contains a large crystalloid and an excentrically located globoid. Rarely two or more globoids are present.

DIAGNOSIS.

Highly characteristic of this seed are the sharply polygonal, pitted epidermal cells (Fig. 177) of the spermoderm, some with, others without, brown contents, and the brown, sclerenchymatized palisade cells (Fig. 176, *P*). The other layers of the spermoderm are also of some diagnostic value. Numerous large aleurone grains (Fig. 178), each with a large crystalloid and a smaller globoid, are seen in turpentine or glycerine mounts.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Böhmer (6, 10, 23); Collin (8); Hanausek, T. F. (48); Planchon et Collin (34); Tichomirow (38).

COLLIN: Tourteau de ricin; ses dangers, ses caractères anatomiques. Jour. pharm. chim. 1903.

GRAM: Om Frösskallens Bygning hos Euphorbiaceerne. On the structure of the spermoderm of euphorbiaceous seeds. Bot. Tidskrift. 1896. **20**, 358.

Gris: Note sur le développement de la graine du Ricin. Ann. Soc. nat. Bot. 1861, **15**, 5; 1862, **17**, 312; 1864, Sér. V. **2**, 5.

Kayser: Beiträge zur Entwicklungsgeschichte der Samendecken bei den Euphorbiaceen mit besonderer Berücksichtigung von *Ricinus communis* L. Ber. Pharm. Ges. 1892, **2**, 45.

Pammel: On the Seed Coats of the Genus *Euphorbia.* Contributions from Shaw School of Bot. 1891, No. 8, 543.

Schlotterbeck: Beiträge zur Entwicklungsgeschichte pharmakognostisch wichtiger Samen. Inaug.-Diss. Bern, 1896.

CANDLENUT.

The seeds of the candlenut tree (*Aleurites triloba* Forst., *A. Moluccana* (L.) Willd., order *Euphorbiaceæ*) yield a valuable oil used as food and in the arts. The tree is a native of the Moluccas and the southern islands of Polynesia, but is cultivated in tropical and subtropical regions of both the Old and the New World, including Florida and California.

The fruit is nearly globular, 5–6 cm. in diameter, and has two locules, each containing a single dark-brown, chestnut-shaped seed about 30 mm. in diameter, consisting of a hard spermoderm 2–5 mm. thick, a bulky endosperm, and in the axis of the endosperm a thin embryo with broadly heart-shaped, leaf-like cotyledons and a short radicle.

HISTOLOGY.

Wichmann made a thorough microscopic study of candlenut seeds on the market in 1880, and found the structure in most details analogous to that of the castor-bean. His material, however, lacked tissues corresponding to the epidermis and subepidermal layer of the castor-bean, and his observations as well as my own further indicate that such tissues may have been present in the original seed but were removed before reaching the market.

Spermoderm (Fig. 179). 1. *Thin-walled Palisade Cells* (*p*). Although probably not the epidermis, this is the outermost layer of the commercial seed. The prismatic, thin-walled cells are colorless and filled with a granular mass of calcium carbonate.

2. *Sclerenchymatized Palisade Cells* (*P*). These cells correspond in structure with the brown palisade cells of the castor-bean, but are characterized by their much greater height, which varies from 1.5 to over 2.5 mm. Both the porous walls and the cell-contents are of a brown color.

3. *Parenchyma* (*s*). This layer is characterized by the narrow, greatly elongated pores of the cell-walls and the cystolith-like masses of calcium oxalate contained in the cells. The cells increase in size from without inward and have intercellular spaces at the corners.

4. *Compressed Cells* form the inner layers.

The Endosperm contains, in addition to oil, aleurone grains from 8–24 μ in diameter, similar to those of the castor-bean. A crystalloid is always present in each grain, also one to two globoids.

Calcium oxalate occurs in crystal clusters in the cells but not in the aleurone grains.

Embryo. The cells are smaller than those of the endosperm, but like the latter contain oil and aleurone grains.

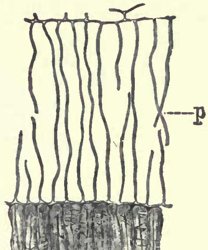


FIG. 179. Candlenut (*Aleurites triloba*). Spermoderm in cross section. *p* thin-walled palisade cells; *P* brown sclerenchymatized palisade cells; *s* spongy parenchyma. (MOELLER.)

DIAGNOSIS.

The cake is distinguished from castor-pomace by the greater height of both layers of palisade cells (Fig. 179). The colorless outer layer contains granules of calcium carbonate; the inner brown cells have amorphous contents. These latter often reach 2.5 mm. in length. The narrow, elongated pores in the parenchyma of the third layer are more or less evident. Aleurone grains similar to those of the castor-bean form a large part of the material.

POPPY-SEED.

The poppy plant (*Papaver somniferum* L. order *Papaveraceæ*), a native of the Orient, is now cultivated in various parts of the Old and New World.

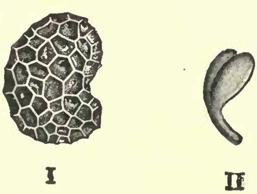


FIG. 180. Poppy (*Papaver somniferum*). *I* seed. *II* embryo. ×16. (WINTON.)

Two distinct varieties are recognized, the white, and the black or blue. The white poppy is grown chiefly for the production of opium, the black for the seed, from which is expressed poppy oil.

The anatropous seeds (Fig. 180), are very small, seldom over 1 mm. long, and kidney-shaped, one end being slightly broader than the other.

The hilum and chalaza are in a notch, connected by a short raphe, the chalaza being nearer the broad end of the seed. Under the lens the

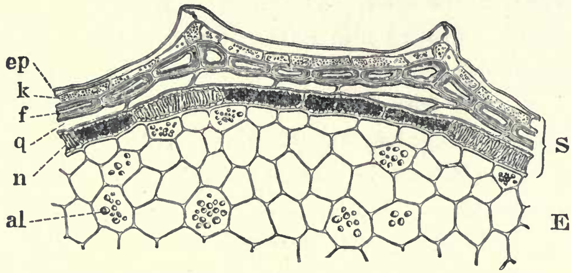


FIG. 181. Poppy Seed in cross section. *S* spermoderm consists of *ep* epidermis, *k* crystal layer, *f* fiber layer, *q* cross cells and *n* netted cells; *E* endosperm, contains *al* aleurone grains. ×160. (WINTON.)

surface is beautifully reticulated. The straight embryo is embedded in the bulky endosperm.

HISTOLOGY.

Spermoderm (Fig. 181, *S*; Fig. 182). Cross sections are prepared after soaking the seed in water and may be cleared with chloral or alkali. After soaking the whole seed for about 24 hours in $1\frac{1}{4}$ per cent sodium hydrate solution, the first four layers readily separate from the fifth.

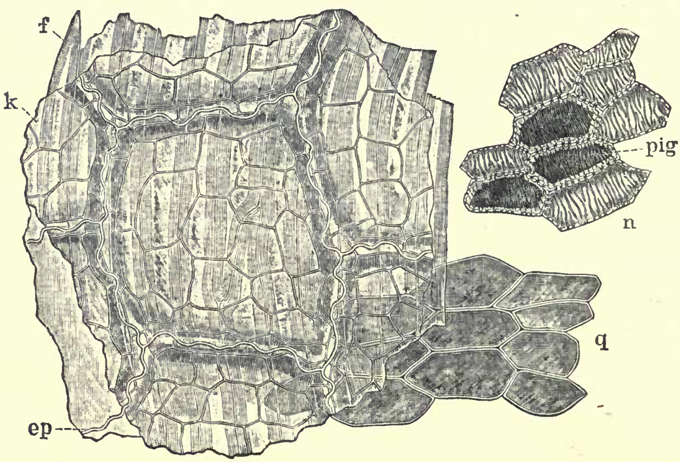


FIG. 182. Poppy. Spermoderm in surface view. *ep* epidermis; *k* crystal layer; *f* fiber layer; *q* cross cells; *n* netted cells containing *pig* pigment. ×160. (WINTON.)

Subsequent treatment with hydrochloric acid dissolves out the calcium oxalate, and staining with chlorzinc iodine or safranin renders the outer layers more distinct.

1. *The Epidermal Cells* (*ep*) are polygonal and of enormous size, corresponding to the network on the seed. As appears in cross section, the cells are collapsed except in the neighborhood of the radial walls. In surface view the radial walls are sinuous and thin, what are often considered the thick dark walls of this layer being not the walls at all, but the ribs formed by the thickening of the second and third layers.

2. *Crystal Layer* (*k*). On the ribs, the cells of this layer are more or less tangentially elongated, but between the ribs, are isodiametric and polygonal, the elongated cells having longer radial walls than the others, thus contributing to the formation of the ribs. They contain fine, granular crystals of calcium oxalate. Meyer has demonstrated that the blue color is due to the interference of light by the crystals over the brown cells in the background, and is the same phenomenon as causes the apparent blue color of the sky and the iris of the eye. As soon as these crystals are dissolved in hydrochloric acid, the seed appears brown.

3. *Fiber Layer* (*f*). The fibers of this layer are 15–40 μ broad and are parallel to the curved axis of the seed. Seen in cross section, this layer is thickest in the ribs, the walls throughout being distinctly thickened and stratified. In surface view they are rendered more distinct by chlorzinc iodine.

4. *Cross Cells* (*q*). The fourth layer consists of moderately thick-walled, transversely elongated, pointed cells arranged side by side in rows. The walls are impregnated with a brown material.

5. *Netted Cells* (*n*). Owing to the netted-veined, colorless walls and the presence of deep brown contents, these cells are particularly striking. They are arranged transversely and are often side by side in rows. The cell-contents are insoluble in alkali and do not give the tannin reaction.

Some authors designate the cells of this layer "pigment cells," notwithstanding the fact that in the white poppy they do not contain pigment.

Meyer, Tschirch and Oesterle, Vogl, and Hanausek describe an inner layer of thin-walled cells, but this layer is not usually evident except in the vicinity of the hilum.

The Endosperm (Fig. 181, *E*) contains aleurone grains up to 3 μ in the outer layers and 7 μ in the inner layers, each grain containing several globoids and crystalloids.

Embryo. In the cotyledons there is only one layer of palisade cells, and these cells are only slightly elongated. The aleurone grains are like those of the endosperm.

DIAGNOSIS.

Poppy-seeds are used in bread and pastries; poppy-cake, the by-product in the manufacture of poppy-oil, is fed to cattle.

The ground material should be examined directly, also after soaking successively in 1¼ per cent soda solution and hydrochloric acid, or after treatment by Hebebrand's method. Fragments consisting of the first four layers, showing the ribs, and separate fragments of the layer of netted cells with brown contents, are readily identified (Fig. 182).

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Benecke (2); Berg (3); Böhmer (6, 10, 23); Collin (8); Hanausek, T. F. (16, 17, 48); Harz (18); Meyer, A. (27); Planchon et Collin (34); Tschirch u. Oesterle (40); Vogl (45).

GODFRIN: Etude histologique sur les tégument séminaux des Angiospermes. Soc. d. Sci. d. Nancy, 1880, 109.

HOCKAUF: Beobachtungen an Handelsmohnen. Chem. Ztg. 1903.

MACH: Mohn und Mohnkuchen. Landw. Vers.-Stat. 1902, **57**, 421.

MEUNIER: Les téguments séminaux des Papaveracées. "La Cellule," Recueil de Cytologie et d'Histologie générale. 1891, **7**, 377.

MICHALOWSKI: Beitrag zur Anatomie und Entwicklungsgeschichte von *Papaver somniferum* L., I Theil, Dissertation, Grätz, 1881.

TSCHIRCH: Entwicklungsgeschichtliche Studien. Schw. Woch. Chem. Pharm. 1897, **35**, No. 17.

WINTON: The Anatomy of Certain Oil Seeds with Especial Reference to the Microscopic Examination of Cattle Foods. Conn. Agr. Exp. Sta. Rep. 1903, 175.

OLIVE.

Of the vegetable oils commonly used as foods or in the arts, olive oil is the only one derived from the flesh of a fruit (*Olea Europea* L., order *Oleaceæ*).

Olives differ greatly in size and shape according to the variety. When ripe they are of a purple color. Morphologically the fruit is a drupe, corresponding in general structure to the peach and apricot.

HISTOLOGY.

Ripe olives preserved in brine furnish suitable material for studying all the histological elements except the salt-soluble aleurone grains of the endosperm and embryo. After soaking several days in alcohol, the fruit flesh is sufficiently hardened to permit the cutting of sections. These should be soaked for a time in ether to remove fat.

Pericarp. 1. *The Epicarp* (Fig. 183) consists of thick walled polygonal cells about 25 μ in diameter. This layer, as well as the mesocarp, contains a purple pigment, which, as Hanausek first noted, becomes intensely red on addition of concentrated sulphuric acid.

2. *The Mesocarp* contains so much oil, that a clear idea of its structure can be gained only after extraction with ether.

In the outer portion the thin-walled cells are isodiametric, but in the middle and inner portion they are radially elongated. Distributed

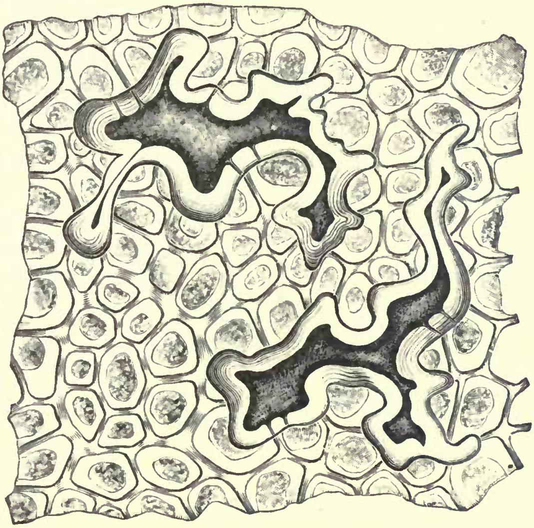


FIG. 183. Olive (*Olea Europea*). Epicarp and two stone cells of the mesocarp, seen from beneath. (MOELLER.)

here and there among this thin-walled tissue are stone cells (Fig. 183) remarkable for their fantastic shapes and especially for the curious beaked, T- or Y-shaped excrescences, occurring at the ends and angles. Being colorless, the stone cells are not readily found in water mounts, especially if the oil has not been extracted; but on treatment with alkali, they are colored a bright yellow.

3. *Endocarp* (Fig. 184, *a*, *m*, *i*). The oblong stone consists of a dense conglomerate of sclerenchymatized tissues forming an envelope about the seed 1–3 mm. thick. In cross sections prepared by grinding on a whetstone (p. 13), the curious forms and grouping of the stone cells are clearly evident. These stone cells, like those of the mesocarp, are colorless and diverse in form, although lacking conspicuous excrescences. In the outer and middle layers, both elongated and isodiametric

forms occur, the former extending in all directions; in the inner layers all the cells are transversely elongated. Most of them are thick-walled, with exceedingly narrow lumen; occasional cells, however, have lumens broader than the walls.

An innermost layer (*en*) composed of compressed thin-walled parenchyma cells lines the cavity.

Spermoderm (Fig. 184). 1. *The Epidermal Cells* (*ep*) seen in surface view are highly characteristic, owing to their unequally swollen

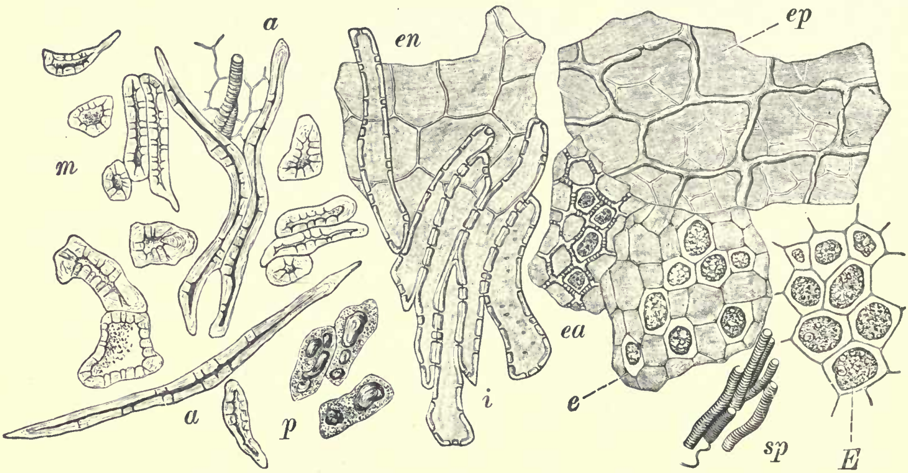


FIG. 184. Olive. Elements in surface view. *p* oil cells of mesocarp; *a*, *m*, *i* stone cells and fibers of endocarp; *en* inner layer of endocarp; *ep* outer epidermis of spermoderm; *ea* outer layer of endosperm; *E* and *e* parenchyma of cotyledon; *sp* spiral vessel. ×160. (MOELLER.)

and colorless walls. They are more or less elongated, often reaching a length of 300 μ.

2. *Parenchyma.* Beneath the epidermis are several layers of thin-walled cells, through which ramify the numerous bundles. The cells in the outer layers are sharply polygonal; those further inward are rounded; the innermost are compressed. Numerous crystals of various forms are the conspicuous contents.

The Endosperm (Fig. 184) makes up the bulk of the seed.

1. *The Outer Layer* (*ea*) consists of irregularly polygonal cells. Both the outer walls and the outer ends of the radial walls are greatly thickened, the latter, in surface view, showing distinct pores.

2. *Parenchyma.* The remainder of the endosperm consists of thin-walled parenchyma, containing fat and proteid grains.

Embryo (*E*, *e*). Embedded in the axis of the endosperm is the straight embryo, with oblong cotyledons several times the length of the radicle. The cells are smaller and thinner-walled than those of the endosperm, although containing the same materials.

DIAGNOSIS.

Olive Pomace, consisting of the fruit pulp obtained as a by-product in the manufacture of olive oil, is used to some extent as a cattle food, and also as an adulterant.

Characteristic of this pulp are the grotesque stone cells (Fig. 183) becoming bright yellow on the addition of alkali, and the purple pigment of the epicarp and mesocarp, which changes to an intense red on addition of sulphuric acid.

Olive Stones are ground to a considerable extent in France as an adulterant for white pepper and other spices, and are shipped to other European countries, as well as to America.

The stone cells (Fig. 184, *a*, *m*, *i*) are characterized by their colorless walls and contents, and by the bright yellow color produced by alkali, while those of pepper are yellow and often contain a brownish material. Especially characteristic are the large epidermal cells (*ep*) of the spermoderm with swollen walls. The outer layer of the endosperm (*ea*) is also a striking element, but like the last, can be found only after diligent search.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Böhmer (23); Hanausek, T. F. (10, 16, 17); Macé (26); Moeller (29); Schimper (37); Villiers et Collin (42); Vogl (45).

Also see Bibliography of Pepper, p. 509.

BOTTINI: Sulla struttura dell'oliva. Nuov. giorn. bot. ital. 1889, **21**, 369.

HANAUSEK, T. F.: Ueber einige, gegenwärtig im Wiener Handel vorkommende Gewürzfälschungen. Ztschr. Nahr.-Unters, Hyg. 1894, **8**, 95.

LANDRIN: Falsification du poivre a l'aide des grignons d'olive. Jour. pharm. **10**, 194.

PART IV.

LEGUMES.

LEGUMES (*Leguminosæ*).

Plants of this family are characterized morphologically by their pods which are dehiscent on both sutures, physiologically by their power of assimilating atmospheric nitrogen through the agency of micro-organisms residing in the root tubercles, and anatomically by the structure of the spermoderm and starch grains.

Most of the species of economic importance belong in the subfamily *Papilionaceæ*, so-called because of their butterfly-like flowers, of which the sweet pea is a type; a few species, however, including the genera *Cassia* and *Ceratonia* have more regular flowers and are classed in the subfamily *Cæsalpinieæ*.

The reserve material of the seed in many species is starchy, but in some species starch is absent, the reserve material being largely proteid matter or, in exceptional cases, cellulose.

Microscopic Characters of Leguminous Seeds.

Only the seeds of most legumes are of interest to the food microcopist, but notable exceptions are the green pods of snap beans eaten as a vegetable, the dried saccharine husks of the carob bean, serving as food for man and beast, and the shells of the peanut used as an adulterant of foods.

The Spermoderm (Fig. 186, *S*) in all the species of economic importance has three layers, of which the two outer are one cell thick and the third is several cells thick. An inner epidermis is seldom evident. The hilum in some species is more or less elongated, and pierced through its major axis by a narrow slit.

1. *The Palisade Layer* (*pal*), or outer epidermis, is of great diagnostic value, not only in determining that a leguminous product is present, but also in naming the particular legume. The cells are prismatic, with thick walls, and in all the common species except the peanut and tonka bean are much higher than broad. The lumen in the inner portion is broader than in the outer, where it is usually a mere line.

On both sides of the hilum slit two layers of palisade cells are present

(Fig. 185, p^1 and p^2), while immediately beneath the slit in many species is a group of sclerenchyma cells with reticulated walls (*Tri*), which, according to Tschirch and Oesterle, probably serve to prevent the entrance of fungi.

The "light line," a light-colored band of different refractive power from the rest of the layer, may be seen in cross section. This line varies

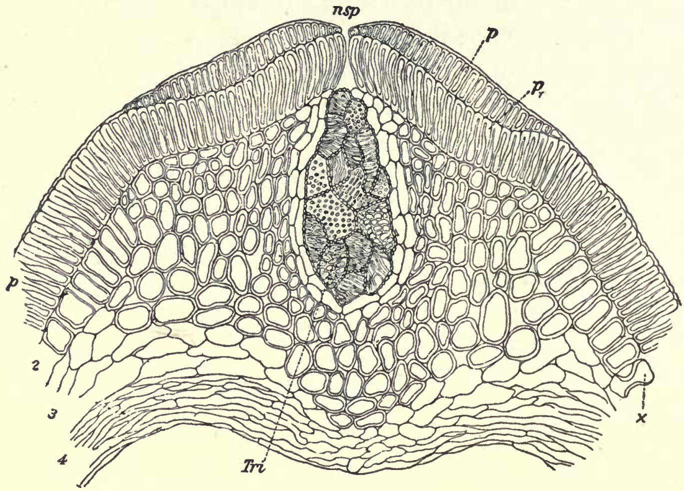


FIG. 185. Pea (*Pisum arvense*). Cross section of spermoderm through *nsp* hilum slit. *p* palisade epidermis with double layer of cells on both sides of the hilum slit; *x* subepidermal layer expanding beneath the hilum into a cushion of cells in which is embedded *Tri* a cluster of porous sclerenchyma cells. (TSCHIRCH and OESTERLE.)

in its breadth and distance from the outer surface according to the species, and is of some importance in diagnosis.

In surface view the cells are sharply polygonal, and often show radiating lines, due to the pores separating the ribs which make up the thickened walls. Focusing on the outer surface it has a shagreen-like appearance due to the strips which make up the thickened walls (Fig. 190).

After macerating with hot alkali or grinding, the palisade cells become isolated and, owing to their rod-shaped form, assume a horizontal position.

2. *The Column Cells* (*sub*) forming the subepidermal layer are commonly hour-glass or I-shaped (Fig. 189) without evident contents, but in the common bean they are prismatic and contain well-formed crystals of calcium oxalate (Figs. 186 and 187).

In some species the walls of the hour-glass cells are ribbed, giving them in surface view the appearance of a sunburst.

3. *Parenchyma* (*p*), usually of the spongy type, forms several layers, seen to advantage only in surface view. The character of the cells differs in different species and different layers of the same species.

4. *The Inner Epidermis* when present, is of thin-walled cells.

The Perisperm is commonly absent, and when present, as for example in the soy bean, is not of interest.

The Endosperm in some species forms an obliterated layer (e.g. bean, pea, etc.), in others a dense, horny structure with thickened cell-walls (e.g. carob bean), and in others still a tissue with thick mucilaginous inner-cell membranes (e.g. fenugreek).

Embryo (*C*). This is always relatively large and has large cotyledons, while in seeds lacking a well-developed endosperm it makes up by far the greater part of the seed. The contents are proteid matter and fat together with, in many species, starch.

Leguminous starch (*am*) is characterized by the large ellipsoidal grains with elongated, more or less branching hilum, although in some species the forms of the grains are irregular, and in the peanut and tonka bean are normally globular.

The hilum is indistinct in some species, but is brought out clearly by polarized light.

Chief Characters.

Of chief value in recognizing a leguminous seed are the thick-walled palisade cells, the subepidermal cells (usually hour-glass shaped) and, when present, the ellipsoidal starch grains with elongated hilum.

The parenchyma of the spermoderm is usually spongy. An endosperm with thickened walls is present in some species.

Analytical Key to Leguminous Seeds.

A. Seed contains starch.

(*a*) Starch grains evident without treatment with reagents or by direct treatment with iodine solution; seed not aromatic.

* Starch grains globular, under 15 μ in diameter; palisade cells under 25 μ high.

1. Palisade cells in surface view over 25 μ broad with beaded walls and broad lumen........................Peanut (*Arachis hypogaea*).

** Starch grains ellipsoidal, over 15 μ long; palisade cells over 25 μ but under 100 μ high.

+ Palisade cells with flat outer ends.

‖ Column cells prismatic containing crystals.

2. Palisade cells under 60 μ high; column cells thin-walled with large crystals....................Common Bean (*Phaseolus vulgaris*).

3. Palisade cells over 60 μ high; column cells thick-walled with small crystals..........................Spanish Bean (*P. multiflorus*).

|| || Column cells hour-glass shaped without crystals, under 20 μ high.

4. Starch grains irregularly ellipsoidal up to 40 μ long.
Common Pea (*Pisum sativum*, *P. arvense*).

5. Starch grains irregularly ellpisoidal up to 90 μ long.
Adzuki Bean (*Phaseolus Mungo*, var. *glaber*).

6. Starch grains regularly ellipsoidal up to 35 μ long.
China Bean (*Vigna Catjang*).

|| || || Column cells hour-glass shaped without crystals, 25–35 μ high.

7. Starch grains irregularly ellipsoidal up to 65 μ long.
Lima Bean (*Phaseolus lunatus*).

+ + Palisade cells with rounded or pointed outer ends.

8. Palisade cells under 45 μ high with light line up to 10 μ broad.
Lentil (*Ervum Lens*).

9. Palisade cells 50–65 μ high with light line 10–15 μ broad.
Vetch (*Vicia sativa*, *V. villosa*, *V. hirsuta*).

*** Starch grains ellipsoidal, over 15 μ long; palisade cells over 100 μ high.

+ Column cells in one layer, hour-glass shaped.

10. Starch grains up to 40 μ long......Egyptian Bean (*Dolichos Lablab*).

11. Starch grains up to 70 μ long..........Horse Bean (*Faba vulgaris*).

+ + Column cells in several layers, hour-glass shaped, simple in outer, compound in inner, layers.

12. Starch grains up to 50 μ long.............Jack Bean (*Canavalia*).

**** Starch grains ellipsoidal over 15 μ long; palisade cells variable in height (35–125 μ).

13. Palisade cells with rounded outer ends...Chick Pea (*Cicer arietinum*).

(*b*) Starch grains evident only after treatment successively with a mixture of hot ether and alcohol and iodine solution; seed aromatic.

14. Palisade cells over 50 μ high, under 25 μ broad, with dark contents; starch grains globular, under 10 μ.
Tonka Bean (*Coumarouna odorata*).

B. Seed contains no starch, or only traces.

(*a*) Palisade cells pointed; column cells ribbed; endosperm mucilaginous.

15. Palisade cells 30–40 μ high; column cells 15–45 μ broad.
Lucerne (*Medicago sativa*).

16. Palisade cells 60–75 μ high; column cells 30–75 μ broad; seed aromatic.
Fenugreek (*Trigonella Fœnum-Græcum*).

17. Palisade cells 125–150 μ high; column cells 35–75 μ high.
Astragalus (*A. bæticus*).

(*b*) Palisade cells with flat or rounded outer ends; column cells not ribbed.

* Palisade cells straight, under 100 μ high.

18. Palisade cells 50–60 μ high, 6–15 μ broad; column cells 35–50 μ high; easily isolated................Soy Bean (*Glycine hispida*).

19. Palisade cells 60–75 μ high, 3–7 μ broad; column cells 16–25 μ high, endosperm with enormously thickened walls.

Coffee Cassia (*C. occidentalis*).

** Palisade cells straight, over 100 μ high.

20. Palisade cells 150 μ high, blunt spindle-shaped after isolation in water.............................. Soudan Coffee (*Parkia*).

21. Palisade cells 170–250 μ high, with swollen outer walls; endosperm with enormously thickened walls; brown wrinkled bodies in mesocarp, becoming violet on treating with alkali.

Carob Bean (*Ceratonia Siliqua*).

*** Palisade cells geniculate, over 100 μ high.

22. Outer ⅔ of palisade cells straight; inner ⅓ geniculate with dark contents; epidermis of cotyledons porous.

Yellow Lupine (*Lupinus luteus*).

23. Outer ⅔ of palisade cells straight, inner ⅓ geniculate with colorless contents; light line 2–6 μ; epidermis of cotyledon not porous.

White Lupine (*L. albus*).

24. Outer ½ of palisade cells straight, inner ½ geniculate with dark contents; light line narrow; epidermis of cotyledons porous.

Blue Lupine (*L. angustifolius*).

BIBLIOGRAPHY.

BECK: Die Samenschale einiger Leguminosen. Sitzb. K. K. Akad. zu Wien, 1878, **79**.

CHALON: La graine de Légumineuses. Mém. et Pub. Soc. Sci., Arts et Let. du Hainaut, 1875, 55.

GUIGNARD: Embryogénie des Légumineuses. Ann. des Sc. nat., Bot. 1882, Ser. VI, **12**, 68.

MATTIROLO E BUSCALIONI: Ricerche anatomofisiologiche sul tegumenti seminali delle Papilionacee. Reprint from Memorie Accad. Szienze Torino. Ser. II, **42**, 1892.

NADELMANN: Ueber Schleimendosperm der Leguminosensamen. Ber. deutsch. Bot. Ges. 1889, 248.

PAMMEL: On the Structure of the Spermoderm of Several Leguminous Seeds. Bull. Torr. Bot. C. 1886, 17.

PAMMEL: Anatomical characters of the seeds of Leguminosæ, chiefly genera of Gray's Manual. Transact. Acad. Sc. St. Louis, 1899, **9**, 91.

PFÄFFLIN: Untersuchungen über Entwicklungsgeschichte, Bau und Function der Nabelspalte und der darunter liegenden Trachïedeninsel verschiedener praktisch wichtiger Papilionaceen-Samen. Inaug.-Diss., Bern, 1897.

SCHIPS: Ueber die Cuticula und die Anskleidung der Intercellularen in den Samenschalen der Papilionaceen. Ber. deutsch. bot. Ges. 1893, **11**, 311.

SCHLEIDEN: Beiträge zur Entwickelungsgeschichte der Blütenteile bei den Leguminosen und über das Albumen, insbesondere der Leguminosen. 1838.

SCROBISCHEWKY: Recherches sur l'embryogénie des Papilionacées. Bull. Congr. Internat. Bot. et Hortic. Petersburg, 1884, 207.

VAN TIEGHEM: Observations sur la légérité et la structure de l'embryon de quelques Légumineuses. Mém. de Soc. Sc. nat. de Cherbourg, **19**.

COMMON BEAN.

The larger part of the dried beans used as food in Europe and America are the seeds of *Phaseolus vulgaris* Metzger, now regarded by Wittmack as a native of tropical America. To the same species belong the edible-podded varieties—the so-called snap- or string-beans—also certain twining varieties cultivated for the seeds.

The hemitropous seeds are more or less kidney-shaped, although the ratio of length, breadth and thickness varies greatly in the different

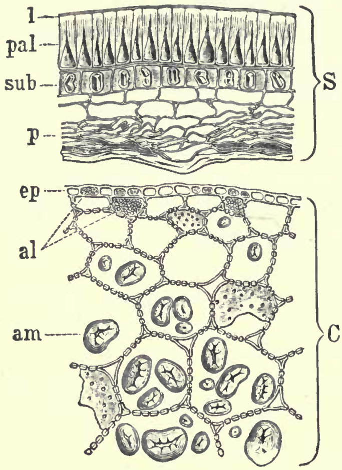


FIG. 186. Common Bean (*Phaseolus vulgaris*). Cross section of outer portion of seed. *S* spermoderm consists of *pal* palisade cells with *l* light line, *sub* subepidermal layer containing calcium oxalate crystals, and *p* spongy parenchyma; *C* cotyledon; *ep* epidermis of cotyledon; *al* aleurone grains; *am* starch grains. ×160. (WINTON.)

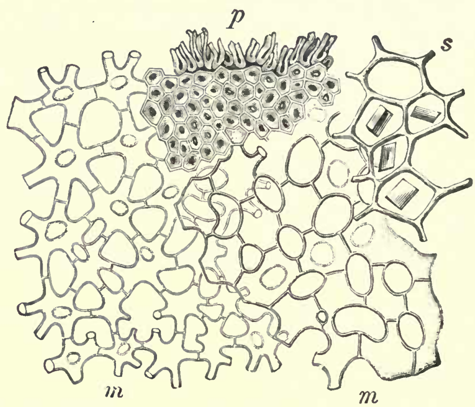


FIG. 187. Common Bean. Elements of spermoderm in surface view. *p* palisade cells; *s* subepidermal cells with crystals; *m* spongy parenchyma. × 300. (MOELLER.)

varieties, some being nearly globular, others much elongated, and still others strongly flattened. In color they are white, black, red, brown, or mottled. The elliptical hilum is situated in the middle of one of the narrow sides. A narrow slit follows the major axis of the hilum, piercing the outer of the underlying tissues. Near one end of the hilum is the micropyle and near the other end is a small wart. The raphe enters the seed at a point near this wart.

HISTOLOGY.

The seed consists of a large embryo closely covered by a thin, brittle spermoderm.

Spermoderm. 1. *The Palisade Cells* (Fig. 186, *pal*; Fig. 187, *p*), as may be seen in cross section, are upward of 60 μ long, with a narrow light line adjoining the cuticle. In the outer portion the cavity is narrow, but broadens toward the inner end. The color of the bean is determined by the color of the contents of these cells. Beneath the hilum there are two layers of palisade cells, both of which are pierced by the hilum slit.

2. *The Column Cells* (Fig. 186, *sub*; Fig. 187, *s*) in this species are not hour-glass shaped as in the pea and many other legumes, but are prismatic without intercellular spaces. The walls are moderately thick, and swell considerably in water or alkali. Each cell contains one, or rarely two, large monoclinic crystals of calcium oxalate, which nearly fills the cavity. The presence of large crystals in the column cells is characteristic of this species. Beneath the hilum this layer is absent.

3. *Spongy Parenchyma* (Fig. 186, *p*; Fig. 187, *m*). The cells are largest and have the thickest walls in the outer layers. In the inner layers they have long, narrow arms and exceedingly thin walls. At the hilum this layer forms a thick cushion.

Embryo. (Fig. 186, *C*; Fig. 188). The two large cotyledons form the bulk of the seed. Fat and proteids are present throughout, as is also starch, except in the epidermal cells.

In the outer epidermis (*ep*) the cells are isodiametric, in the inner epidermis they are tangentially elongated as in the pea.

The cells of the *Mesophyl* are large (often 100 μ), and have thick (4–9 μ) walls with distinct pores. Intercellular spaces of moderate size occur at the angles.

The starch grains vary up to 60 μ in length, the larger grains being, for the most part, ellipsoidal or kidney-shaped, seldom irregularly swollen as in the pea. A conspicuous, branching cleft, appearing black because of inclosed air, is almost always present.

DIAGNOSIS.

Beans usually reach the consumer whole, and therefore unadulterated.

Bean Meal is a comparatively rare article of commerce, used chiefly as a cattle food. Coarsely ground beans have been employed as adulterants of coffee, although less often than peas and other legumes.

The starch (Fig. 186, *am*) is distinguished from pea-starch by the absence of irregularly swollen forms, and the presence of a distinct branching cleft in each large grain. The cell-walls of the endosperm are thick and conspicuously porous, whereas in the pea they are usually thinner and indistinctly porous.

Bean Hulls serve as a cattle food and adulterant. In bean products

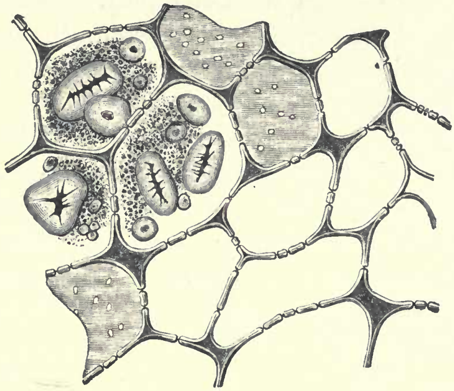


FIG. 188. Common Bean. Cross section of cotyledon showing starch grains. ×300. (MOELLER.)

containing the hulls, the crystal-bearing column cells (Fig. 187, *s*) furnish a ready means of identification.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Böhmer (6); Greenish (14); Hanausek, T. F. (10); Harz (18); Macé (26); Moeller (29); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (45); Wittmack (10).

GULLIVER: On the crystals in the Testa and Pericarp of several Orders of Plants and in the other Parts of the Order of Leguminoseæ. Monthly Micros. Jour. 1873, 259.

HABERLANDT: Ueber die Entwicklungsgeschichte und den Bau der Samenschale bei der Gattung Phaseolus. Sitzb. d. k. k. Akad. zu Wien. 1877, **75**, 33.

KOEHLER: Erbsen, Bohnen, Wicken und deren Müllereiprodukte. Landw. Vers.-Stat. 1901, **55**, 401.

TSCHIRCH: Ueber Starkemehlanalysen. Arch. d. Pharm. 1884, **22**, 921.

SPANISH BEAN.

Of the several varieties of Spanish bean (*Phaseolus multiflorus* Willd.) in cultivation, the scarlet runner and Dutch case-knife bean are the best known. The scarlet runner is grown partly for the brilliant scarlet flowers, and partly for the flattened black and pink mottled seeds. The Dutch case-knife bean has white flowers and seeds.

HISTOLOGY.

In histological structure these beans are much like the common bean, but the palisade cells are longer (60–75 μ) and the column-cells have thicker walls and contain smaller crystals. Although the column cells are prismatic without intercellular spaces, the radial walls are thickest in the middle and diminish in thickness toward both ends, the cavity being, as a consequence, hour-glass-shaped. The cell structure of the embryo and the starch grains are practically the same as in the common bean.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Harz (18); Tschirch u. Oesterle (40).

ADZUKI BEAN.

The adzuki bean (*P. Mungo* var. *glaber* Roxbg.) is highly esteemed in Japan as food for man and has been introduced into the United States. Other varieties of this species are also cultivated in the East.

The plant yields a seed 8–10 mm. long, of a rich wine color.

Characteristic of this seed is the narrow, elongated hilum 2–3 mm. long.

HISTOLOGY.

Spermoderm. 1. *The Palisade Cells* are 75 μ high, 6–15 μ wide, and contain a reddish pigment.

2. *The Column Cells* are hour-glass-shaped like those of the pea. They are 14–20 μ high and 8–20 μ wide.

3. *The Parenchyma* is much the same as in the common bean.

Embryo. The thin-walled cells contain larger starch grains than any other common legume (often 90 μ). In addition to the usual ellipsoidal grains, trefoil and irregular grains, such as occur in the pea, are numerous. Their large size serves to distinguish them from pea-starch and their form as well as size from other leguminous starches.

LIMA BEAN.

The small seeded Lima or Sieva bean (*Phaseolus lunatus* L.) and the true or large-seeded Lima bean (*P. lunatus* var. *macrocarpus* Benth.) are natives of South America, but are grown throughout the Western Hemisphere, the seed being eaten as a vegetable either green or dried. The flattened white seeds of the true Lima bean are 20–25 mm. long and about half as wide.

HISTOLOGY.

Spermoderm. 1. *The Palisade Cells* are 60–80 μ long and 12–20 μ wide.

2. *Column Cells.* These are quite unlike the column cells of the other members of this genus. Their hour-glass form distinguishes them from the corresponding cells of the common and Spanish bean, and their greater height (25–35 μ) from the last named and all the other species of *Phaseolus* here described. The cells are 14–35 μ wide.

3. *Spongy Parenchyma.* The outer and innermost layers contain small cells, the middle layers large cells.

Embryo. The moderately thick-walled cells contain ellipsoidal, reniform and trefoil-shaped grains, which are, on the average longer (up to 65 μ) and broader than in the common bean.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Harz (18).

PEA.

The field pea (*Pisum arvense* L.) is grown both as a forage plant and for the production of mature seeds; the garden pea (*P. sativum* L.) only as a vegetable.

Peas of the former species are smooth, nearly spherical, and of a buff color; those of the latter species are either smooth or wrinkled.

HISTOLOGY.

The Spermoderm (Figs. 189–192) is thin and brittle. The structure at the hilum is shown in Fig. 185; in other parts it is as follows:

1. *The Palisade Cells* (*p*) are 60–100 μ high, a narrow light line immediately adjoining the cuticle. In the inner portion of each cell the cavity is broad and wavy in contour.

2. *The Column Cells* (*t*), of typical hour-glass form, are conspicuous both in cross section and in surface view. They never contain crystals. On heating pieces of the hull with dilute alkali and pressing with the cover-glass, these cells may be isolated, the hour-glass form being especially striking after this treatment. They vary up to 20 μ in height.

3. *Spongy Parenchyma* (Fig. 189, *m*; Fig. 192). The cells decrease in size from without inward.

Embryo. 1. *The Epidermal Cells* (Fig. 193, *ep*) of the cotyledons are tangentially elongated and arranged end to end in rows. They contain aleurone grains and fat, but no starch.

2. *The Parenchyma* (Figs. 193 and 194), making up the remainder of the cotyledons, is composed of large cells with moderately thick, non-porous walls, with intercellular spaces at the angles. Usually, but not always, the walls are thinner than in the bean and the intercellular spaces are larger, often extending from one angle to another.

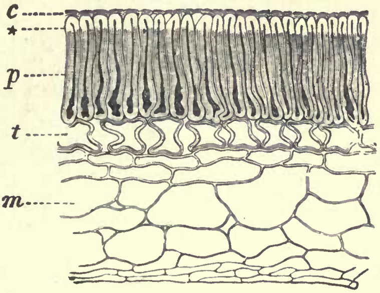


FIG. 189. Pea (*Pisum arvense*). Cross section of spermoderm. *c* cuticle; *p* palisade cells with * light line; *t* hour-glass cells; *sub* subepidermal layer; *m* spongy parenchyma. ×160. (MOELLER.)

The Starch Grains (Fig. 193) are commonly smaller than in the bean (seldom over 40 μ) and among ellipsoidal, reniform, and globular forms, occur many which are characterized by irregular, rounded protuberances. As a rule, comparatively few grains have distinct clefts.

DIAGNOSIS.

Whole Peas, as well as pea hay, are highly prized in many regions as cattle food. Roasted and flattened whole peas are used as substitutes or adulterants for coffee.

Split peas, freed from hulls, are prepared for use in soups and other culinary articles.

Pea Flour, because of its high nutritive value, is an ingredient of many dietary preparations for infants and invalids, as well as for soldiers and others requiring a nutritious and palatable food in a concentrated form.

Many of the starch grains (Fig. 193, *st*) have irregular swollen protuberances, a phenomenon of no little value in discriminating between this and bean-starch. The starch of the adzuki bean also displays this peculiarity. Clefts in the grains are indistinct or wanting. The parenchyma of the cotyledons is seldom as thick as in the bean and shows much less distinct pores. The individual cells are readily separated from one another through the middle lamella, especially after treatment with alkali. This latter treatment, in

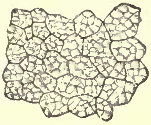


FIG. 190. Pea. Palisade cells in surface view showing the outer surface. ×300. (MOELLER.)

the case of roasted peas, dissolves out the starch grains, leaving a characteristic skeleton of colored proteid material.

Pea Hulls are utilized as a cattle food and an adulterant. A common coffee adulterant in the United States consists of pea hulls made into pellets with molasses and other ingredients.

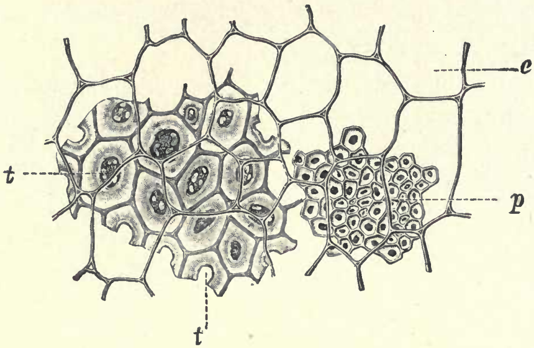


Fig. 191. Pea. Elements of spermoderm in surface view. *p* palisade cells; *t* hour-glass cells (subepidermal layer); *e* parenchyma. ×160. (Moeller.)

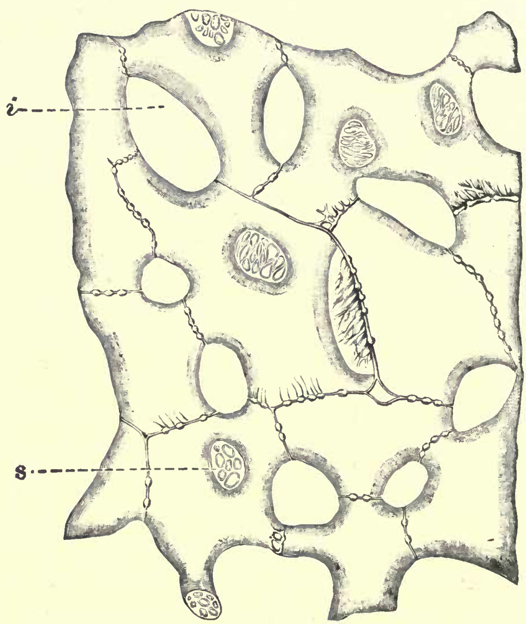


Fig. 192. Pea. Outer layers of spongy parenchyma. *i* intercellular space; *s* porous membrane at end of arm. (Moeller.)

The elements of the hull may be studied in section (Fig. 189), or in surface view (Fig. 191) after scraping with a scalpel. Isolation of the palisade and column cells is accomplished by judicious heating with dilute alkali and sidewise pressure with the cover-glass. The column cells (*t*) are hour-glass in form, without crystals; whereas in the common bean they are prismatic, with large crystals of calcium oxalate.

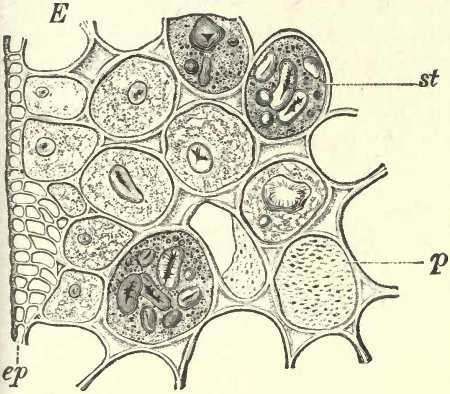


FIG. 193. Pea. Cross section of cotyledon. *ep* epidermis, *p* parenchyma containing *st* starch grains. ×160. (MOELLER.)

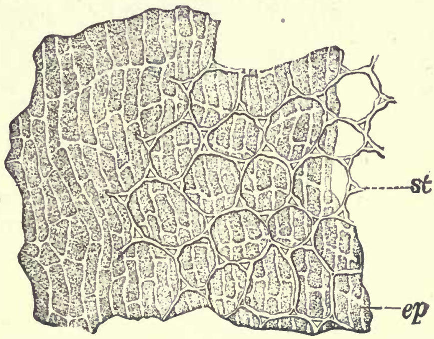


FIG. 194. Pea. Cotyledon tissues in surface view. *ep* epidermis; *st* starch parenchyma. ×160. (MOELLER.)

The height of the palisade cells (60–100 μ) and column cells (up to 20 μ) is of importance in diagnosis.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Böhmer (6, 23); Greenish (14); Hanausek, T. F. (10); Harz (18); Macé (26); Moeller (29, 32); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (45); Wittmack (10).

SEMPOLOWSKI: Ueber den Bau der Schale landwirthschaftlich wichtiger Samen. Landw. Jahrb. 1874, **3**, 823.

LENTIL.

Lentils, the seeds of *Lens esculenta* Moench (*Ervum Lens* L.), have been used in Oriental countries as food for man since very ancient times. Esau sold his birthright for a mess of pottage made from this seed. At present the plant is cultivated chiefly in the countries bordering on the Mediterranean.

The Latin word "lens," meaning primarily lentil, was afterward applied by the philosophers to the biconvex magnifying glass because of its resemblance to the lentil in shape. The seeds are gray-brown or red in color and 5–7 mm. in diameter. The long and narrow hilum, as well as the micropyle and raphe, are on the narrow edge.

HISTOLOGY.

The Spermoderm (Fig. 195, *S*) is 1 mm. thick with layers much the same as in the pea.

1. *The Palisade Cells* (Fig. 195, *pal*) are 45 μ high, 8 μ broad, have rounded outer ends, over which the cuticle is extended in the form of blunt-pointed papillæ. A light line nearly 10 μ broad lies directly beneath the cuticle, but the remainder of the walls are yellow-brown.

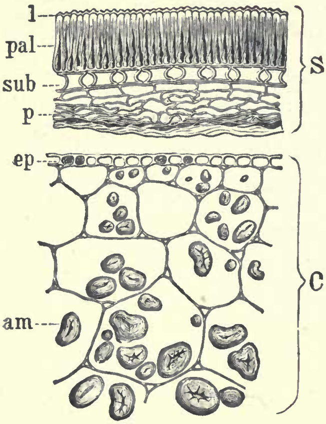


FIG. 195. Lentil (*Lens esculenta*). Outer portion of seed in cross section. *S* spermoderm consists of *pal* palisade cells with *l* light line, *sub* hour-glass cells (subepidermal layer) and *p* spongy parenchyma; *c* cotyledon with *ep* epidermis and *am* starch cells. ×160. (WINTON.)

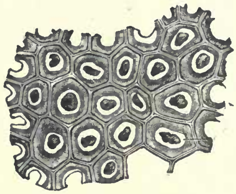


FIG. 196. Lentil. Hour-glass cells (subepidermal layer) of spermoderm in surface view. ×160. (MOELLER.)

2. *The Column Cells* (*sub*) of hour-glass form are 18–35 μ broad and 12–22 μ high. An irregular brown lump nearly fills each cell (Fig. 196).

3. *Spongy Parenchyma* (*p*). The outer layers consist of very small cells without conspicuous intercellular spaces. In the middle layers the

FIG. 197. Lentil Starch. ×300. (MOELLER.)

cells are large, some of them containing a brown substance showing the reaction for tannins.

Embryo (Fig. 195, *C*). The thin-walled cells contain starch grains (Fig. 197) somewhat smaller than those in the bean or pea, the largest being but 40 μ long. In form they are mostly ellipsoidal, although forms with irregular excrescences similar to those occurring in the pea, are not infrequent.

DIAGNOSIS.

Ground lentils are distinguished from bean and pea products by the smaller diameter (maximum 8 μ) of the palisade cells (Fig. 195, *pal*), their rounded or blunt-pointed outer ends, and the broader light line. The starch grains (Fig. 197) are also smaller.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Böhmer (6, 23); Greenish (14); Harz (18); Macé (26); Moeller (29, 32); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (45).
BECK: Vergl. Anatomie der Samen von Vicia und Ervum. Sitzb. Wiener Akad. 1873, **77**.
SEMPOLOWSKI: Ueber den Bau der Schale landwirthschaftlich wichtiger Samen. Landw. Jahrb. 1874, **3**, 823.

CHINA BEAN.

Varieties of *Vigna Catjang* Walp (*V. Sinensis* Endl., *Dolichos Sinensis* L.) are highly prized in the East for their seeds, and in the Southern States as a forage and green manuring crop.

Although known in America as the cow pea or black pea, the plant is more correctly a bean, and the names China bean and black-eyed bean in vogue in Europe are more appropriate.

Black, white with black eyes, yellow, red, brown, and mottled seeded varieties are in cultivation, the size of the somewhat flattened, kidney-shaped seeds varying from 6–10 mm.

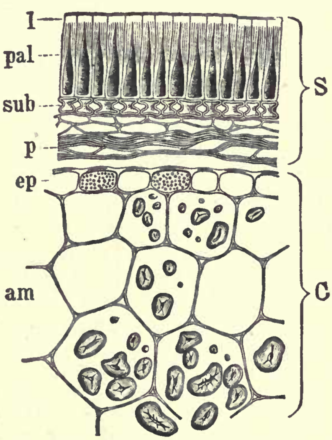


FIG. 198. China Bean (*Vigna catjang*). Outer portion of seed in cross section. *S* spermoderm consists of *pal* palisade cells with *l* light line, *sub* hour-glass cells (subepidermal layer), and *p* spongy parenchyma; *C* cotyledon with *ep* epidermis and *am* starch cells. ×160. (WINTON.)

HISTOLOGY.

The Spermoderm (Fig. 198) consists of: (1) a layer of palisade cells (*pal*) 60–75 μ high and 6–18 μ broad; (2) a layer of column-cells (*sub*) 9–15 μ high and 9–25 μ broad; (3) several compressed layers of spongy parenchyma (*p*).

The Cotyledons (*C*) contain starch grains much like those of the common bean though somewhat smaller (maximum 35 μ).

DIAGNOSIS.

The China bean has smaller starch grains (Fig. 198, *am*) than most of the common legumes. Compared with the large grains of the Lima or the adzuki bean, this characteristic is especially marked. The spermoderm has much the same structure as in the last-named species. The column cells (*sub*) are hour-glass-shaped.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Harz (18); Tschirch u. Oesterle (40).

SOY BEAN.

Numerous varieties of the soy or soja bean (*Glycine hispida* Maxim, *Soja hispida* Moench), natives of the Orient, are grown in China and Japan for the highly nutritious seed, and in Europe and America for forage as well as for the seed.

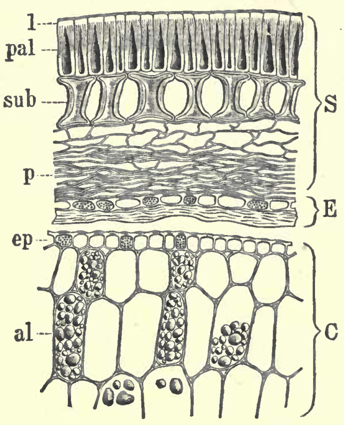


FIG. 199. Soy Bean (*Glycine hispida*). Outer portion of seed in cross section. *S* spermoderm consists of *pal* palisade cells with *l* light line, *sub* hour-glass cells (subepidermal layer), and *p* parenchyma; *E* endosperm consists of aleurone cells and compressed cells; *C* cotyledon, with *ep* epidermis and *al* aleurone cells. ×160. (WINTON.)

The yellow, brown or black seed (5–10 mm.) in some varieties is nearly globular, in others slightly flattened and elongated.

HISTOLOGY.

Marked features of the soy bean are the high column cells of the spermoderm, the presence of an endosperm and the absence of starch in the cotyledons.

The Spermoderm (Fig. 199) is closely united with the layers of the endosperm.

1. *The Palisade Cells* (*pal*) of this seed are of about the same height (50–60 μ) and diameter (6–15 μ) as those of the common bean and, like the latter, may or may not have colored contents, according to the color of the seed.

2. *Column Cells* (*sub*). This layer is of about the same thickness as the palisade layer, being thicker than in any of the other common legumes. The hour-glass or I-shaped cells are usually 35–50 μ high, but about the hilum they often reach 150 μ. In width they vary from 16–36 μ. Since the cells have a marked tendency to separate from the adjoining layers and from each other, isolated cells may usually be found in considerable numbers in surface mounts obtained by scraping the inner surface of the hull, or in the ground seed.

3. *The Spongy Parenchyma* (*p*) is much compressed and presents no characteristic features.

An Endosperm (*E*) consisting of a single layer of moderately thick-walled aleurone cells (15–45 μ) and obliterated cells, marks this seed as an exception among legumes. The aleurone cells as seen in surface view are rectangular or polygonal with proteid content.

Embryo (*C*). The thin-walled cells contain large aleurone grains, sometimes 25 μ in diameter. Starch is entirely absent.

DIAGNOSIS.

The absence of starch, the presence of long (35–50 μ) I-shaped column cells (Fig. 199, *sub*) readily isolated from the surrounding tissues, and the presence of an endosperm layer (*E*), furnish ready means for the identification of this seed.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Böhmer (6. 23); Harz (18); Moeller (29); Tschirch u. Oesterle (40).

HANAUSEK, T. F.: Die Sojabohne. Irmischia II, 1882, No. 7, 44.

HANAUSEK, T. F.: Ueber das Vorkommen von Stärkemehl in der Sojabohne. Ztschr. allg. österr. Apoth.-Ver. 1884, 474.

HARZ: Ueber den Stärkegehalt der Sojabohne. Ztschr. allg. österr. Apoth.-Ver. 1885, 40.

TRIMBLE: The Soja Bean. Amer. Jour. Pharm. 1897, 69.

EGYPTIAN BEAN.

Seeds of the Egyptian or hyacinth bean (*Dolichos Lablab* L., *Lablab vulgaris* Savi.) are much eaten in the Tropics.

In macroscopic structure they are characterized by their flattened form and large hilum.

HISTOLOGY.

Strongly developed in this species are: (1) *The Palisade Cells*, 125 μ or more high; (2) *The Column Cells* of hour-glass form, 35–55 μ high and of about the same width. *The Spongy Parenchyma* is not remarkable. *The Starch Grains* vary up to 40 μ in length.

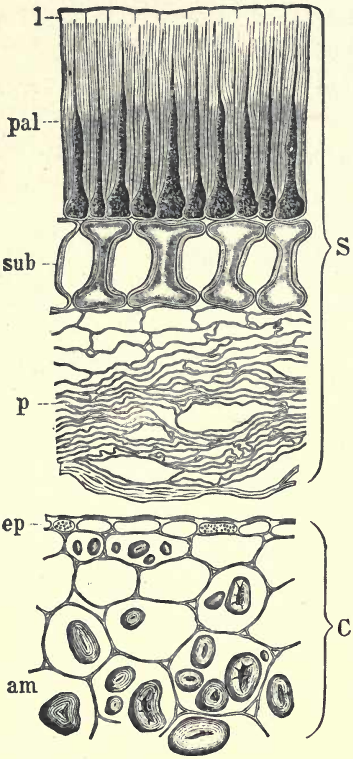


FIG. 200. Horse Bean (*Faba vulgaris*). Outer portion of seed in cross section. *S* spermoderm consists of *pal* palisade cells with *l* light line, *sub* hour-glass cells (subepidermal layer), and *p* spongy parenchyma; *C* cotyledon with *ep* epidermis and *am* starch cells. ×160. (WINTON.)

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Harz (18); Tschirch u. Oesterle (40).

HORSE BEAN.

The name bean, now largely applied to plants belonging to the genus *Phaseolus*, formerly was appiled almost exclusively to the varieties of *Faba vulgaris* Moench (*Vicia Faba* L.) of which the horse bean, also known as the broad or Windsor bean, is one of the best known examples. Beans of this species were cultivated by the ancient Egyptians, Trojans, Greeks, and Romans, as well as by the lake dwellers and other prehistoric races.

It is not remarkable that so ancient a plant should have numberless varieties widely different, especially as to the size, shape, and color of the seeds. The best known varieties have slightly flattened seeds 8–12 mm. long and two-thirds as broad. The conspicuous elongated hilum is not on the side of the seed, but at one of the ends.

HISTOLOGY.

Spermoderm (Fig. 200). The palisade and column cells are remarkable for their large size.

1. *The Palisade Cells* (*pal*) are 150–175 μ long and 12–20 μ broad. A light line 20–25 μ broad, directly beneath the cuticle, is distinguishable,

although the whole outer half of the layer is colorless. The cell-walls of the inner portion are yellow-brown.

2. *Column Cells* (*sub*). This layer has strongly developed cells, 35–50 μ high and 35–60 μ broad. They are hour-glass-shaped with a cavity only slightly constricted in the middle. The walls are rather thick.

3. *Parenchyma* (*p*). The outer layers are of large cells with few intercellular spaces; the middle layers are of similar cells with deep brown contents; the inner layers are of compressed spongy parenchyma.

Embryo (*C*). The isodiametric cells, with non-porous walls similar to those of the pea, contain starch grains (*am*) up to 70 μ in length. Broadly ellipsoidal grains, many scarcely longer than broad, also irregular forms, are common. The hilum is often indistinct.

DIAGNOSIS.

The enormous height of the palisade cells (Fig. 200, *pal*) and their broad light line, also the large column cells (*sub*), serve to identify this seed in powder form. Although the starch grains (*am*) are of large size, and more nearly circular in outline than in most common legumes, too much dependence should not be placed on this distinction.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Böhmer (6, 23); Harz (18); Macé (26); Tschirch u. Oesterle (40).

GODFRIN: Étude histologique sur les tégument séminaux des Angiospermes. Soc. d. Sci. d. Nancy. 1880, 109.

SEMPOLOWSKI: Ueber den Bau der Schale landwirthschaftlich wichtiger Samen. Landw. Jahrb. 1874, **3**, 823.

SPRING VETCH.

The spring vetch or tare (*Vicia sativa* L.) has been cultivated since prehistoric times both for green fodder and seed, the latter being used to some extent for human food. The tare of the scriptures is not this plant, but darnel (*Lolium temulentum*).

Seeds of the spring vetch are dark colored, nearly globular, and 5 mm. or less in diameter.

HISTOLOGY.

The Spermoderm of the vetch and lentil are much alike in structure.

1. *The Palisade Cells* are characterized by the rounded or blunt-pointed outer ends, the thick cuticle, the broad light line (10–15 μ) and

the dark color and moderate thickness of the walls in the inner portion of the layer. They are 50–65 μ high and 6–10 μ broad.

2. *The Column Cells* (13–25 μ high, 22–40 μ broad) are hour-glass-shaped and contain a dark material.

3. *Parenchyma.* This tissue is not spongy, but true parenchyma without marked intercellular spaces. The middle layers contain a dark, tannin-like material.

Embryo. The non-porous walled cells contain ellipsoidal and irregularly-shaped starch grains each with a more or less distinct cleft.

DIAGNOSIS.

Both the lentil and vetch have palisade cells with rounded or blunt-pointed outer walls, but in the latter seed these cells are somewhat higher and have a broader light line (10–15 μ).

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Böhmer (6); Harz (18); Macé (26); Tschirch u. Oesterle (40).

BECK: Vergl. Anatomie der Samen von Vicia und Ervum. Sitzb. Wiener Akad. 1873, **77**.

SEMPOLOWSKI: Ueber den Bau der Schale landwirthschaftlich wichtiger Samen. Landw. Jahrb. 1874, **3**, 823.

WINTER VETCH.

The winter or hairy vetch (*Vicia villosa* Roth.), like the spring vetch, is a common forage plant in Europe and parts of the East.

Although the seeds are somewhat smaller than those of the latter plant, they have practically the same structure.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Böhmer (23); Harz (18).

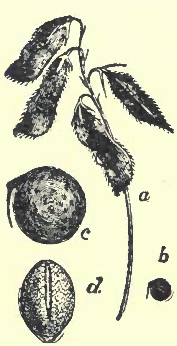


FIG. 201. Hairy Vetch (*Vicia hirsuta*). *a* fruit branch; *b* seed, natural size; *c* and *d* seed, enlarged. (NOBBE.)

HAIRY VETCH.

Among the leguminous plants infesting European grain fields the hairy vetch (*Vicia hirsuta* Koch) is one of the commonest, the seeds often occurring in considerable quantity in the grain.

The seeds are globular, about 2.5 mm. long, with dark spots on a somewhat lighter field (Fig. 201).

The palisade cells are about 50 μ high, the spool-shaped column cells about 15 μ. Starch grains up to 30 μ long fill the cells of the cotyledons.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Vogl (45).

YELLOW LUPINE.

Lupines are cultivated chiefly for forage or green manuring, but in parts of Europe the seeds are used for human food, and especially as a substitute for coffee.

The common yellow lupine (*Lupinus luteus* L.) has a flattened, kidney-shaped seed 6–9 mm. long and 5–7 mm. wide, with black spots on a light background. The round hilum is not situated in the cove, but in the center of one of the lobes.

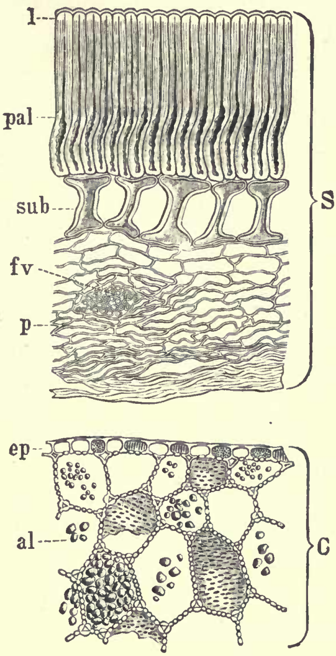


Fig. 202. Yellow Lupine (*Lupinus luteus*). Outer layers of seed in cross section. *S* spermoderm consists of *pal* palisade cells with *l* light line, *sub* hour-glass cells (subepidermal layer), and *p* spongy parenchyma with *fv* fibro-vascular bundle; *C* cotyledon with *ep* epidermis and *al* aleurone cells. ×160. (Winton.)

HISTOLOGY.

Spermoderm (Fig. 202, *S*; Fig. 203). 1. *The Palisade Cells* (Fig. 202, *pal*; Fig. 203, *p*) are 140–170 μ long and 8–18 μ broad, with rounded outer ends. The roughened cuticle is 3–6 μ thick and the narrow underlying light line 2–6 μ broad. The outer portion of each cell for two-thirds its entire length has straight walls and a narrow cavity; the inner portion has two slight bends in opposite directions. Those cells lying underneath the dark-colored spots on the surface of the seed contain a dark substance situated chiefly in the inner portion of the cavity.

2. *The Column Cells* (Fig. 202, *sub*; Fig. 203, *t*) are 35–70 μ high, 25–50 μ broad, hour-glass- or spool-shaped, much constricted in the middle.

3. *Parenchyma* (Fig. 202, *p*; Fig. 203, *sch*). The cells in the outer and middle layers are sharply polygonal with thin, finely-porous walls, which appear distinctly beaded in surface view. Compressed cells make up the inner layers.

Embryo (*C*). As noted by Böhmer, the outer epidermal cells of the cotyledons are finely porous; these pores, however, are confined to the radial walls and the edges of the tangential walls.

The remainder of the cotyledons consists of isodiametric cells with much swollen, porous walls, often 15–25 μ thick. This thickening is especially marked at the angles. Ovoid aleurone grains up to 20 μ, often containing large crystalloids, are the only visible cell-contents. Starch is entirely absent.

DIAGNOSIS.

All the common lupines have high palisade cells (Fig. 202, *sub*), geniculate in their inner portions, hour-glass-shaped subepidermal cells

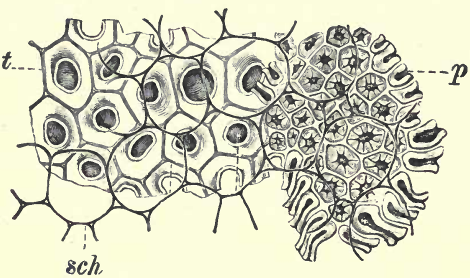


FIG. 203. Yellow Lupine. Elements of spermoderm in surface view. *p* palisade cells; *t* hourglass cells (subepidermal layer) showing contour of base and constriction; *sch* spongy parenchyma. ×160. (MOELLER.)

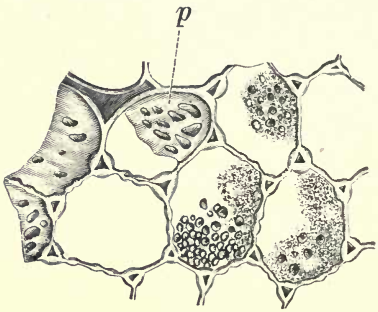


FIG. 204. Yellow Lupine. Collenchyma cells of cotyledon with aleurone grains. *p* porous wall. ×300. (MOELLER.)

(*sub*) and thick-walled cotyledon cells containing aleurone grains (*al*), but no starch.

In the yellow lupine, the outer two-thirds of each palisade cell (Fig. 202, *pal*) is straight (distinction from blue lupine), and the inner geniculate portion often contains dark contents (distinction from white lupine). The sharply polygonal cells in the outer layers of the parenchyma of the spermoderm, as well as in the epidermis of the cotyledons, are distinctly porous (distinction from white lupine).

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Böhmer (23); Harz (18).

SEMPOLOWSKI: Ueber den Bau der Schale landwirthschaftlich wichtiger Samen Landw. Jahrb. 1874, 3, 823.

WHITE LUPINE.

The white-flowered lupine (*Lupinus albus* L.) has light-colored, flattened, almost lenticular seeds somewhat larger (often 10 mm.) than those of the yellow and blue species. A depression is present in the center of each of the flat sides.

HISTOLOGY.

The palisade cells and column cells are of the same size and structure as those of the yellow lupine, except that the light line of the palisade cells is broader (15–20 μ) and the contents are colorless. The cells of the spermoderm and the outer epidermis of the cotyledons are not evidently porous.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Harz (18); Moeller (29); Vogl (45).

GODFRIN: Étude histologique sur les tégument séminaux des Angiospermes. Soc. d. Sci. d. Nancy. 1880, 109.

SEMPOLOWSKI: Ueber den Bau der Schale landwirthschaftlich wichtiger Samen. Landw. Jahrb. 1874, **3**, 823.

BLUE LUPINE.

The type of *Lupinus angustifolius* L. has mottled seeds; the variety *leucospermus*, white seeds. Both have blue flowers. The seeds are rounded reniform, 5–7 mm. long.

HISTOLOGY.

The structure corresponds with that of the yellow lupine, except as regards the palisade layer, which has a distinct line of demarcation a little less than half way between the outer and inner end. In the outer portion the walls are straight, of even texture, and the cavity is without contents; in the inner portion the walls are geniculate, of uneven texture, and the ragged cavities contain a dark material near the line of demarcation. The light line is narrow, as in the yellow lupine, but the outer end of the cell is not rounded.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Hanausek, T. F. (10); Harz (18); Vogl (45).

GUNDRISER: Ueber ein Kaffeesurrogat aus den Samen der blauen Lupine (*Lupinus angustifolius*). Ztschr. Nahr.-Unters. Hyg. 1892, **6**, 373.

SEMPOLOWSKI: Ueber den Bau der Schale landwirthschaftlich wichtiger Samen. Landw. Jahrb. 1874, **3**, 823.

CHICK PEA.

The East Indians prepare from the seeds of the chick pea (*Cicer arietinum* L.) various articles of daily food, as also do the Spanish and French; the inhabitants of Southern Europe and of some of the Western States of the United States utilize them as a substitute for coffee.

Cicer is the old Latin name, and the English "chick" is a corruption of the same word, although suggesting the resemblance of the seed to a

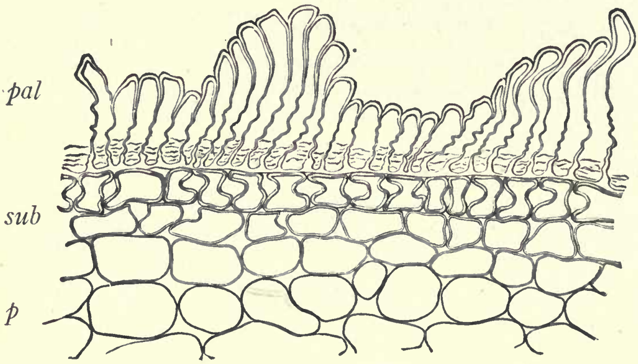


FIG. 205. Chick Pea (*Cicer arietinum*). Cross section of spermoderm. *pal* palisade cells; *sub* hour-glass cells (sub epidermal layer); *p* spongy parenchyma. ×160. (MOELLER.)

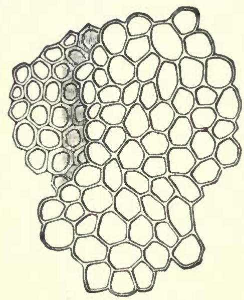


FIG. 206. Chick Pea. Palisade cells in surface view. ×160. (MOELLER.)

chick. The specific name "*arietinum*" was adopted because of the imagined resemblance of the seeds to a ram's head.

The irregularly-globular seeds vary from 7–14 mm. in diameter, and from light buff to dark brown in color. They are encircled on one side by a groove, through the middle of which passes the raphe, and on the other by a ridge ending in a pointed projection at the micropyle. A circular hilum 1 mm. in diameter is situated at the base of this projection.

HISTOLOGY.

Spermoderm (Fig. 205). 1. *The Palisade Cells* are characterized by their variable length (35–125 μ) and by their broad lumens (Fig. 206), the walls being thickened only at the extreme outer and inner ends. The thin radial walls are finely wrinkled toward the inner end. The cells are 12–20 μ broad.

2. *The Column Cells* are hour-glass-shaped, 20–30 μ high and 25–45 μ broad.

3. *The Parenchyma* is much the same as in the common pea.

Embryo. The isodiametric cells of the embryo also resemble those of the common pea. They contain broadly ovoid, sometimes nearly globular, starch grains up to 35 μ in length.

DIAGNOSIS.

The irregular height and thin walls of the palisade cells (Fig. 205, *pal*) suffice for the detection of this seed.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Harz (28); Moeller (29); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (45).

SOUDAN COFFEE.

The negroes in Soudan and other parts of Africa prepare from the seeds and other parts of *Parkia Africana* R. Br. various articles of diet,

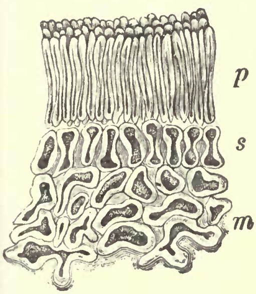


FIG. 207. Soudan Coffee (*Parkia Africana*). Spermoderm in cross section. *p* palisade cells; *s* hour-glass cells (subepidermal layer); *m* parenchyma. ×160. (MOELLER.)

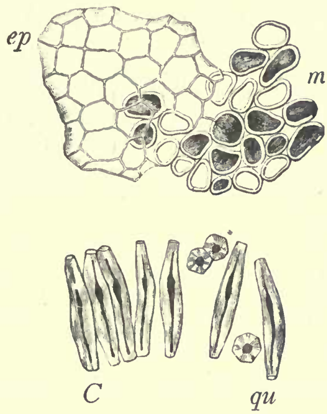


FIG. 208. Soudan Coffee. Elements of spermoderm. *C* isolated palisade cells; *qu* palisade cell in end view; *m* parenchyma; *ep* inner epidermis. ×160. (MOELLER.)

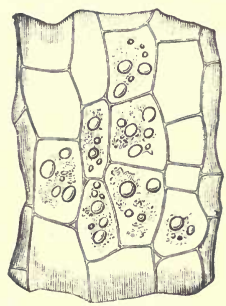


FIG. 209. Soudan Coffee. Tissues of cotyledon. × 160. (MOELLER.)

including a substitute for coffee. *P. Roxburgii* Don. is said to be a valuable food plant in the Indian Archipelago.

HISTOLOGY.

Spermoderm (Fig. 207). The intercellular substance of the *Palisade Layer* is dissolved by soaking in water and the cells (150 μ high and 15 μ broad) are liberated. After this treatment the isolated cells are characterized by their blunt, spindle-shaped form (Fig. 208, *C*).

Both the *Column Cells* and the *Spongy Parenchyma* have thick walls.

The Embryo (Fig. 209) is thin-walled and contains protoplasm and fat, but no starch.

DIAGNOSIS.

Examined in water the blunt spindle-shaped palisade cells (Fig. 208, *C*), the thick-walled column cells and spongy parenchyma (*m*), and the thin-walled cells (Fig. 209) of the starch-free embryo, are the important features.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Moeller (29).

JACK BEAN.

Several tropical and subtropical species of *Canavalia* yield edible seeds, the most important being *C. ensiformis* DC. and *C. obtusifolia* DC. Both are used as coffee substitutes.

The Jack bean or Chickasaw Lima (*C. ensiformis*) is grown to some extent in the southern part of the United States both for human food and feeding stock.

The ovoid beans (15 mm. long) are white with a red eye about the long (5–7 mm.) hilum.

HISTOLOGY.

Spermoderm. 1. *The Palisade Cells* are nearly colorless, 125–150 μ high and 10–22 μ wide. Their great height distinguishes them from the palisade cells of species of *Phaseolus*. The thin cuticle when separated bears the impressions of the cells beneath (Fig. 210).

FIG. 210. Jack Bean (*Canavalia ensiformis*). Cuticle with imprint of palisade cells. (MOELLER.)

2. *The Column Cells* (Fig. 211) over the body of the seed are in four or more layers and beneath the hilum form a spongy mass upwards of 2 mm. thick. Those in the first layer are 25–45 μ high and 25–60 μ broad. In the inner layers one finds all transitions from typical hour-glass cells, to fantastic compound or branching forms such as are shown in Fig. 211, and finally to parenchyma. Brown contents are present in the cells beneath the hilum.

3. *Parenchyma.* This layer presents no remarkable features.

Embryo (Fig. 212). The moderately thick-walled, porous cells of the cotyledons, containing ellipsoidal starch grains up to 50 μ, recall the corresponding tissue of the common bean.

DIAGNOSIS.

Identification, whether in coffee or other food products, is not usually difficult, owing to the great height of the palisade cells and the several

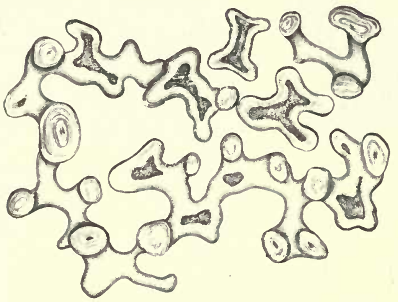


FIG. 211. Jack Bean. Subepidermal cells of spermoderm. $\times$160. (MOELLER.)

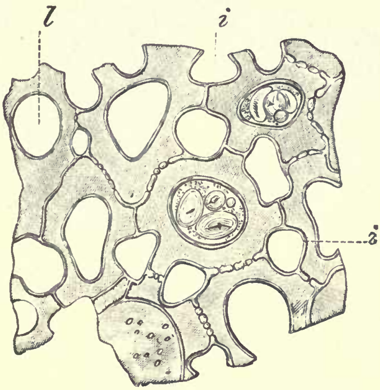


FIG. 212. Jack Bean. Cotyledon tissue showing *i* intercellular spaces and *l* section of cell arm. $\times$160. (MOELLER.)

layers of column cells (Fig. 211). The starch (Fig. 212) is of much the same size and form as that of the common bean.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Moeller (29).

FENUGREEK.

Seeds of fenugreek (*Trigonella Foenum-Graecum* L.), remarkable alike for their curious shape, aromatic odor, and anatomical structure, have been employed as a drug both in human and veterinary practice for many centuries, especially in India, Asia Minor, Egypt, the Barbary States, and Southern Europe. They are also used as food by the women of Northern Africa to give plumpness to their forms.

The outline of the slightly flattened, brown seed is quadrilateral, and the form of both the cotyledons and radicle is clearly evident on the exterior (Fig. 213). The radicle is bent parallel to the cotyledons and the longer axis of the seed (Fig. 214). Under a lens, the hilum is seen to be situated near the apex of the radicle.

HISTOLOGY.

Cross-sections, cut after soaking the seed in water, show a spermoderm, a well-developed endosperm, and an embryo, both the latter being free from starch.

FIG. 213. Fenugreek (*Trigonella Foenum-Graecum*). *a* seed, natural size; the others enlarged. (NOBBE.)

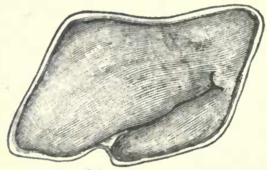


FIG. 214. Fenugreek. Seed with spermoderm partially removed showing cotyledon and radicle. (MOELLER.)

The Spermoderm (Fig. 216, *S*; Fig. 215) has the three layers of a typical legume.

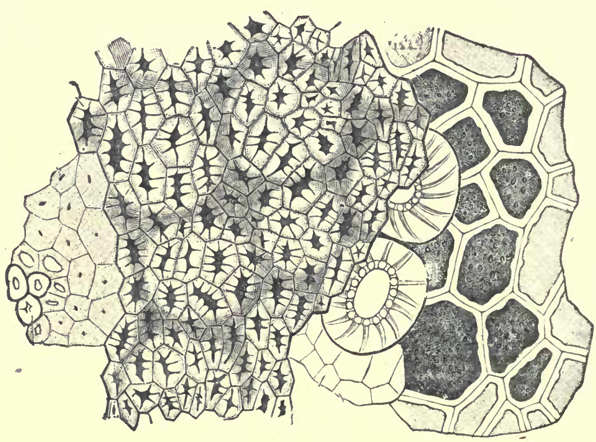


FIG. 215. Fenugreek. Elements of seed in surface view. *cut* cuticle and blunt palisade cells; *pal* pointed palisade cells; *sub* subepidermal cells and parenchyma; *a* aleurone cells of endosperm. (TSCHIRCH.)

1. *The Palisade Cells* (Figs. 215 and 216, *pal*), 60–75 μ high and 8–20 μ broad, have narrow cavities in the outer, broad cavities in the

inner portions. On the outer surface the side walls are continued into pointed or, less often, blunt ends 8–20 μ long, projecting into an outer mucilaginous coat, the latter being indistinct in water and entirely invisible on the addition of alkali. The cells with blunt ends are higher than the pointed cells. A narrow light line 3–6 μ is situated 25–35 μ from the outer ends of the cells.

2. *The Column Cells* (Figs. 215 and 216, *sub*), although but 15–20 μ high, are quite as remarkable as the palisade cells. They are hour-glass-shaped, but the inner end is much broader than the outer. Particularly striking are the ribs, which may be seen either in cross section or in surface view, in the latter case presenting a beautiful radiating effect. Their great breadth, 30–75 μ, is a notable feature.

3. *Parenchyma* (Fig. 216, *p*) with wavy walls and occasional intercellular spaces completes the spermoderm.

An Endosperm (Fig. 216, *E*), glassy when dry, mucilaginous when wet, makes up nearly half the volume of the seed.

1. *Aleurone Cells* (Figs. 215 and 216, *a*). A single layer of cells (15–45 μ) containing small aleurone grains envelops the embryo, and extends also between the cotyledons and the radicle.

2. *Mucilage Cells* (*muc*). Tschirch has shown that each cell has a very thick mucilaginous inner membrane, which is evident on adding glycerine slowly to a water preparation. In sections mounted in water only the thin primary membrane is evident. The cells appear to be empty.

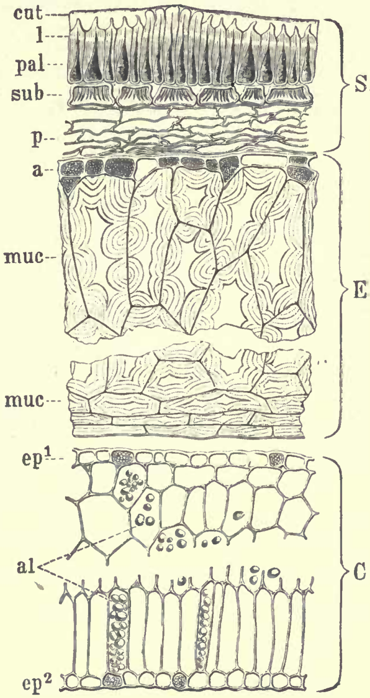


FIG. 216. Fenugreek. Seed in cross section. *S* spermoderm consists of *pal* palisade cells with *cut* cuticle and *l* light line, *sub* subepidermal layer, and *p* parenchyma; *E* endosperm consists of *a* aleurone cells and *muc* mucilage cells; *C* cotyledon, with ep^1 and ep^2 epidermal layers and *al* aleurone cells. ×160. (WINTON.)

Embryo (*C*). The hard yellow cotyledons and radicle contain aleurone grains (*al*) but no starch. Usually three layers of palisade cells underlie the inner epidermis.

DIAGNOSIS.

Fenugreek is a common ingredient of condimental cattle foods and condition powders, where it is recognized by its characteristic taste and odor.

The high, pointed palisade cells (Figs. 215 and 216, *pal*) with mucilaginous outer membranes (*cut*), the ribbed column cells (*sub*), and the aleurone cells (*a*) are all easily found in fragments of the hull. Starch is absent throughout.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Harz (18); Hassall (19); Meyer, A. (27); Moeller (31); Planchon et Collin (34); Tschirch (39); Tschirch u. Oesterle (40).

GODFRIN: Étude histologique sur les tégument séminaux des Angiospermes. Soc. d. Sci. d. Nancy. 1880, 109.

DE LANESSAN: Sur la structure des graines du *Trigonella Foenum Graecum* et la présence d'un albumen dans ces graines. Bull. de la soc. Linn. de Paris séance du 4 juillet 1877, 134.

SEMPOLOWSKI: Ueber den Bau des Schale landwirthschaftlich wichtiger Samen. Landw. Jahrb. 1874, **3**, 823.

COFFEE CASSIA.

Seeds of coffee cassia or Mogdad-coffee (*Cassia occidentalis* L.) are raised in parts of Africa, the East and West Indies, and other tropical regions as a substitute for coffee.

Although a legume, the seed in external appearance does not resemble at all those of any other common member of the family. It is flattened obovoid, 4–6 mm. long, 3–4 mm. broad, its shape reminding one of the sesame seed. Its color is dark gray. An elliptical spot on the middle of each flattened side is dull and lusterless; the remainder of the surface, however, is lustrous, owing to an enamel-like coating, which readily flakes off from the dry seed. The embryo, consisting of two thin but broad heart-shaped cotyledons and a short, straight radicle, is embedded in a horny endosperm.

HISTOLOGY.

After soaking in water for 24 hours, the outer coats form a slimy mass, which can be separated for study in surface view. The soaked seed also serves for cutting sections of the endosperm and embryo, but the dry or partially swollen seed is better suited for sections of the outer coats.

The Spermoderm (Fig. 217) is closely united with the endosperm.

1. *Palisade Cells* (*p*). These are 60–75 μ high and 3–7 μ broad, the breadth being less than in most members of the family. A striking characteristic is the cuticular membrane, which is not a cuticle proper, but is made up of the metamorphosed outer portions of the palisade cells. Cross sections show that in the elliptical spots already mentioned this cuticular membrane is 30–35 μ thick, or nearly half the height of the cells, though in other parts it is only about 12 μ. That it is derived from the cells proper is indicated by the faint markings perpendicular to the

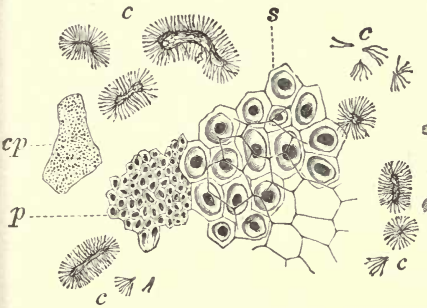


FIG. 217. Coffee Cassia (*Cassia occidentalis*). Elements of spermoderm. *p* palisade cells in surface view; *c* isolated cells; *cp* cuticular plates; *s* subepidermal cells. (MOELLER.)

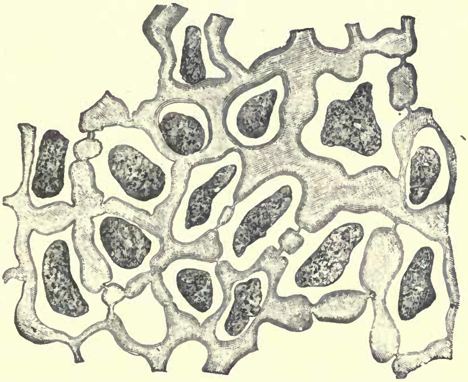


FIG. 218. Coffee Cassia. Cells of endosperm with brown contents. ×160. (MOELLER.)

surface, which correspond to the radial walls of the inner portion of the layer. These are more distinct in the broader portion of the membrane. The enamel-like scales (*cp*) which separate from the dry seed consist of this membrane, although over the spots the fusion is more complete and no such separation takes place. The light line is confined entirely to the inner portion of the layer, being most distinct beneath the thick portion of the cuticular membrane. About two-thirds of the distance from the line of separation of the cuticular membrane to the inner surface of the layer there is noticeable a line of demarcation, caused by the presence of dark contents in the cell cavities, which are there somewhat inflated. In surface view the membrane displays peculiar zigzag walls. Moeller was the first to call attention to the disintegration of the palisade cells through swelling, which takes place after soaking for a day or two in water. The cuticular membrane is not affected by this treatment, but the cells proper are reduced to a mass of hair-like bodies, shown in Fig. 217, *c*.

2. *The Column Cells* (*s*) are 16–25 μ long, 25–40 μ broad, and have somewhat thickened walls.

3. *The Parenchyma Cells* are also thick-walled.

Endosperm (Fig. 218). This resembles the horny endosperm of the carob bean, consisting of cells with enormously swollen walls and brown proteid contents. Cross sections are elliptical, bisected by the narrow, band-like sections of the cotyledons.

Embryo. The thin cotyledons have two rows of palisade cells on the inner surface. They contain proteids and fat.

DIAGNOSIS.

This seed is one of the few belonging to the legume family that contains no starch. The cuticular membrane is alike characteristic both in section and surface view. It is thickest on the elliptical spots. The small breadth of the palisade cells, their length, and the horny character of the endosperm, further aid in identification. If time permits, the effect of soaking the material for a day or two in water should be noted.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Hanausek, T. F. (10); Moeller (29); Vogl (45).
MOELLER: Ueber Cassia-Samen. Bot. Ztg. 1880, 38, 737.

ASTRAGALUS.

The coffee astragalus (*Astragalus baeticus* L.) is found wild in Spain and Portugal, and is cultivated in other parts of Europe for its seeds, which, after roasting, are said to have a true coffee flavor. "Swedish Continental Coffee," a popular substitute for coffee, is a preparation of this seed.

The seeds resemble fenugreek in color, shape, and size. They are brown, more or less rhombohedral with flattened ends, and are upward of 5 mm. long and about two-thirds as broad. The position of the radicle is distinctly marked on the surface.

HISTOLOGY.

In anatomical structure also, the seeds of astragalus and fenugreek are very similar, the chief difference being in the size and structure of the palisade cells.

Spermoderm (Fig. 219). 1. *The Palisade Cells* (*p*) are colorless, 125–150 μ high, and 12–20 μ broad. They are somewhat geniculate like the palisade cells of the lupine. Although there is no distinct line of demarcation, the cavity in the inner portion is broader and more irregular than in the outer.

2. *Column Cells* (*t*). These are hour-glass-shaped, 16–40 μ high, and 35–75 μ broad. Distinct ribs are conspicuous both in cross section and surface view.

3. *Parenchyma.* This layer is much compressed and presents no interesting features.

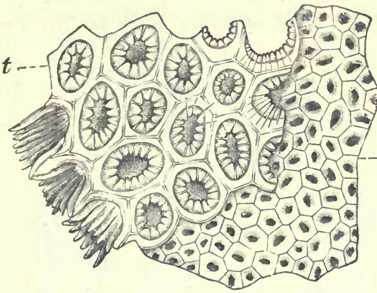


FIG. 219. Astragalus (*A. baeticus*). Surface view of *p* palisade cells and *t* subepidermal cells. ×160. (MOELLER.)

Endosperm. 1. *An Aleurone Layer* of more or less rectangular cells 25–50 μ broad forms the outer coat.

2. *Mucilage Cells* much like those of fenugreek constitute the horny inner portion of the endosperm. Viewed in water, only the faint outline of the cells is visible.

Embryo. Proteid matter and fat form the reserve material. Starch is not present. The cells of the cotyledons are thronghout thin-walled and somewhat elongated, those in the inner layers being pronounced palisade cells.

DIAGNOSIS.

All the tissues are practically the same as in fenugreek, except the palisade cells, which are fully twice as high and are neither swollen nor pointed at the outer extremities. These cells are geniculate and nearly colorless. In surface view the ribbed column cells (Fig. 219, *t*) remind one of sunbursts, but this appearance is common to fenugreek, alfalfa, and some other leguminons seeds. Starch is absent.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Hanausek, T. F. (10); Harz (18); Moeller (29).

LUCERNE.

Although grown only as a forage crop, the seeds of lucerne or alfalfa (*Medicago sativa* L.) occur as an impurity in wheat, when this crop follows alfalfa in rotation.

The curious spiral pod contains small seeds 2–3 mm. long, with a prominent ridge over the radicle (Fig. 220).

HISTOLOGY.

In microscopic as well as macroscopic structure, the seed corresponds closely with fenugreek, except that the dimensions of the parts are much smaller.

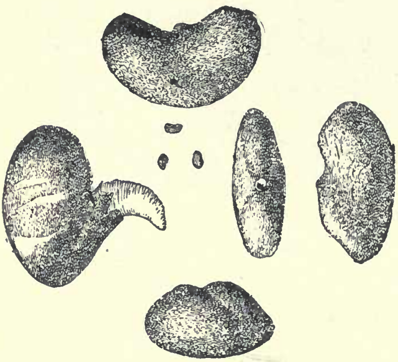


FIG. 220. Lucerne (*Medicago sativa*). Seeds, natural size and enlarged. (NOBBE.)

Spermoderm. The palisade cells, with pointed and mucilaginous outer membranes, are 30–40 μ high and 9–15 μ broad; the ribbed column cells are 10–15 μ high and 15–45 μ broad.

The Endosperm of aleurone and mucilage cells, and the embryo containing aleurone grains but no starch, are very like the corresponding parts of fenugreek.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Harz (18).

PEANUT.

Formerly the peanut (*Arachis hypogaea* L.) was thought to be a native of the Old World,but more recent investigations indicate that it is a Brazilian plant which was introduced into other regions in early colonial times.

At the present time, peanuts are grown in Africa, Southern Europe, India, China, Japan, and the Islands of the Pacific, largely for the production of oil and oil cake, the latter serving as food for man and cattle, and in the United States for consumption as roasted peanuts and in peanut confectionery. Peanut hay, consisting of the stalks, leaves, and immature pods is utilized as a cattle food. About 4,000,000 bushels of peanuts are annually consumed in the United States, the larger part being roasted and sold on the street.[1]

The African variety, grown not only in Africa, but also in India and other parts of the eastern hemisphere, as well as in North Carolina, yields

[1] Handy: U. S. Dept. Agr., Farmers' Bul. No. 25

a small pod with seeds rich in oil. A variety with larger pods (often 4–5 cm. long), but less oily seeds, is extensively grown in Virginia, yielding the nuts commonly roasted by venders. Tennessee produces two varieties, the white and the red. A small podded variety is grown in Spain partly for the production of oil, and partly for the cake which, mixed with chocolate and spices, is a common food for the lower classes. The Spanish peanut is also cultivated to a limited extent in America.

Peanuts of the varieties named usually contain two seeds, less often one, rarely three. Costa Rica produces a variety with long pods containing

FIG. 221. Peanut (*Arachis hypogaea*). Fruit, natural size. (WINTON.)

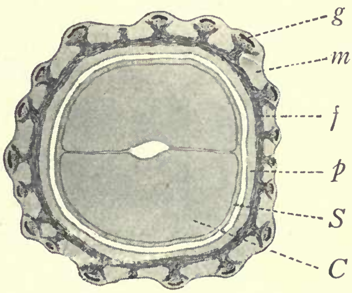


FIG. 222. Peanut. Cross section of fruit. *m* mesocarp, *f* fiber layer and *p* parenchyma, of the pericarp; *g* fibro-vascular bundle; *S* spermoderm; *C* cotyledon. ×4. (WINTON.)

four to five seeds. A variety grown in Argentine Republic has pods of a deep orange color.

The peanut belongs to a small group of legumes which ripen their fruit below ground. Shortly after blooming the flower stalks bend downward until the young fruit is completely buried in the soil. If for any reason this does not occur the fruit fails to ripen.

The dry pod, or pericarp, is brittle and easily broken with the fingers. Ten or more longitudinal ridges with anastomosing branches form more or less distinct reticulations on the outer surface (Fig. 221). Beneath the surface is a spongy tissue, further inward a thin but hard woody coat (Fig. 222, *f*), and still further inward, forming the lining of the pod, a papery tissue (*p*) with a silky luster. In the early stages of ripening the seeds completely fill the pod, and as a result of this crowding the adjacent surfaces are flattened in a diagonal plane. This flattened surface is at the hilum end of the upper seed, at the chalaza end of the lower seed. When ripe the seeds only partly fill the cavity. The united spermoderm and perisperm form a thin skin, red or brown on the outer, colorless or yellow on the inner surface, on which are veins formed by the raphe and the five branches radiating from it at the chalaza.

The elongated cotyledons (Fig. 222, *C*) are longitudinally grooved on the inner surface.

HISTOLOGY.

The Pericarp (Figs. 223 and 224), or shell, while morphologically corresponding with the pod of other legumes, exhibits some remarkable peculiarities traceable partly at least to the conditions encountered while ripening in the soil. Not only is it deprived of all chlorophyl and con-

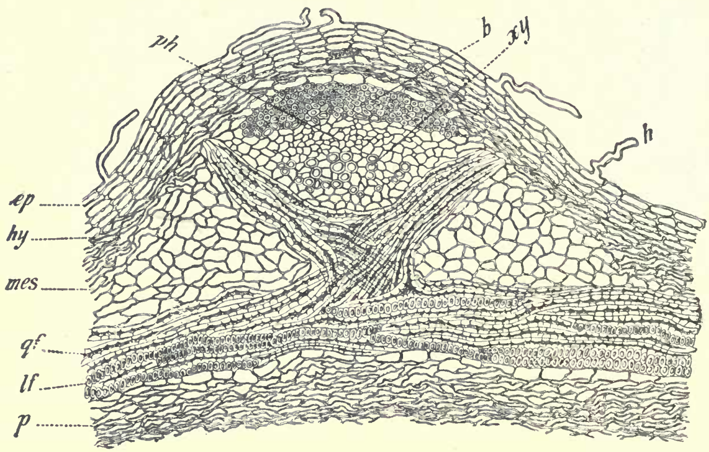


FIG. 223. Peanut. Pericarp in cross section. *ep* epicarp with *h* hair; *hy* hypoderm; *mes* mesocarp; *qf* transversely elongated fibers; *lf* longitudinally elongated fibers; *p* parenchyma; *b* bast fibers, *ph* phloem and *xy* xylem, of a fibro-vascular bundle. ×80. (WINTON.)

sequently of the photosynthetic power of the leaf, but, on the other hand, is provided with root hairs, and presumably possesses to some degree the absorptive function of a true root. In other words, the pericarp, although morphologically a leaf, acts physiologically as a root.

1. *The Epicarp Cells* (*ep*) have such thin walls that they are seen with difficulty in surface view. In cross section, especially after staining with safranin, the presence of typical root hairs, arising from the center of many of the epidermal cells, is evident. These hairs are not usually present on the peanuts sold by venders, due probably to their removal by cleaning or by friction of one against the other in the bags.

2. *Hypoderm* (*hy*). The cells of one or more layers beneath the epidermis have thin non-porous walls, but further inward the walls are

thick and conspicuously porous. Owing to these pores as well as their quadrilateral shape the cells are readily identified in powdered shells.

3. *The Mesocarp* (*mes*), or more properly the outer parenchyma layer, consists of thin-walled cells which become obliterated to a large extent on ripening. Over the bundles this layer is thin or lacking.

4. *Fiber Layer* (Fig. 223, *qf*, *lf*; Fig. 224, *f*, *z*, *g*, *h*, *k*, *t*). A thin but

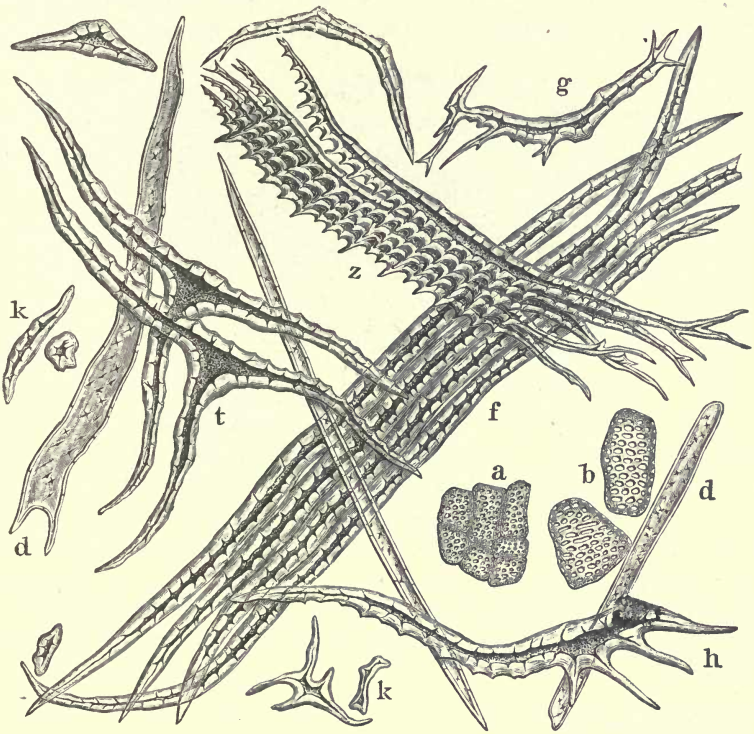


FIG. 224. Peanut. Isolated elements of the pericarp. *a* and *b* cells of the hypoderm; *f*, *z*, *k*, *h*, *t*, *d* and *g* cells of the fiber layer. ×160. (WINTON.)

hard coat of fibers extended in different tangential directions gives rigidity to the pericarp. Many of these fibers bear rows of saw-teeth (*z*), between which lie the crossing fibers of an adjacent layer. At the end they are often branched, giving rise to halberd-shaped (*h*) and other curious forms. Many other remarkable cells varying greatly in size, form and wall thickness occur in this layer.

The ridges forming the reticulations of the nut are but channeled outgrowths of this layer, formed by remarkable T- (*t*) and L-shaped fibers. Often in partially macerated specimens one finds a series of these angled fibers, part of each belonging to the fiber-layer proper, the remainder to a ridge.

In the channels of these outgrowths run the fibro-vascular bundles with well-marked bast fibers (*b*), phloem (*ph*), and xylem (*xy*).

5. *Inner Parenchyma* (*p*). Cross sections of partly ripe seeds show a thick inner layer of pith-like cells, with triangular intercellular spaces at the corners. At full maturity, especially after drying the seeds, the compressed cells of this layer form the papery lining of the shell.

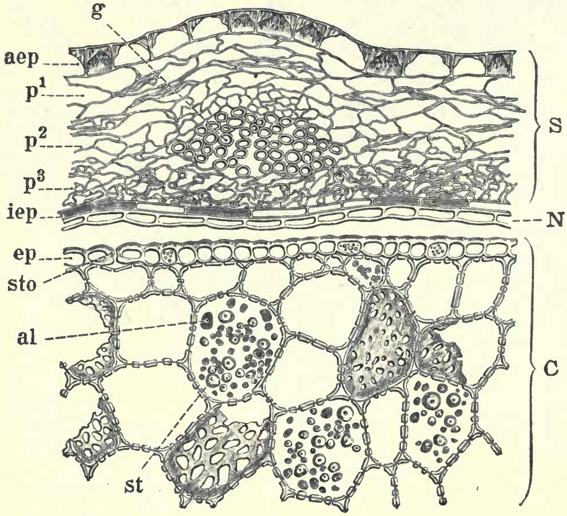


FIG. 225. Peanut. Seed in cross section. *S* spermoderm consists of *aep* outer epidermis, p^1 parenchyma, p^2 and p^3 spongy parenchyma, and *iep* inner epidermis; *g* fibro-vascular bundle; *N* perisperm; *C* cotyledon consists of *ep* epidermis with *sto* stoma and the porous parenchyma cells containing *st* starch grains and *al* aleurone grains. ×160. (WINTON.)

The Spermoderm (Fig. 225, *S*; Fig. 226) and perisperm form a thin dry skin which may be readily separated and sectioned either dry in paraffine, or wet between pieces of pith. As recommended by T. F. Hanausek, sections should be treated either with hydrochloric acid and alkali, or with Javelle water, in order to make the inner epidermis of the spermoderm evident.

1. *The Outer Epidermis* (*aep*) corresponds with the palisade layer of other legumes, although the two appear at first sight to have nothing in common. The cells are 15–25 μ high and 25–50 μ broad. Cross sections show that the inner walls are thin but that the radial walls increase in thickness from within outward, and as a consequence the cavities are more or less triangular in shape.

Radially elongated pores pierce the thickened portion of the walls, forming ribs. Examined in surface view the sharply polygonal cells with thickened and porous radial walls present a characteristic appearance.

When it is considered that the palisade cells of nearly all legumes are polygonal in surface view and have ribbed radial walls, increasing in thickness from within outward, it is evident that these cells differ from

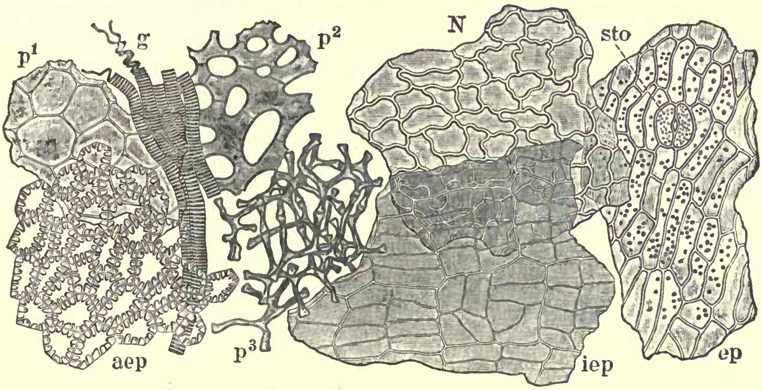


FIG. 226. Peanut. Elements of the seed in surface view. *aep* outer epidermis of spermoderm; p^1 parenchyma; p^2 and p^3 spongy parenchyma; *g* bundle; *iep* inner epidermis of spermoderm; *N* perisperm; *ep* epidermis of cotyledon with *sto* stoma. ×160. (WINTON.)

the type merely in that they are broader, higher, and have a broader lumen.

2. *Subepidermal Layer* (p^1). Column cells such as characterize other legumes are not present, the layer being of thin-walled parenchyma cells without intercellular spaces.

3. *Parenchyma.* The character of the cells varies from ordinary parenchyma (p^1) in the outer layers to spongy parenchyma with moderate-sized intercellular spaces in the middle layers (p^2) and then to a very striking spongy parenchyma, with narrow branching cells and relatively large intercellular spaces in the inner layers (p^3). These latter aid in identification. Strongly developed vascular elements occur in the raphe bundles and its branches.

4. *Inner Epidermis* (*iep*). Treatment of sections with Javelle water brings into evidence the inner epidermis. In surface preparations treated in the same manner, and stained with safranin, the cells are quadrilateral, usually elongated, with often marked evidence of division and subdivision of the mother cells.

Perisperm (Figs. 225 and 226, *N*). A single layer of moderately thick-walled cells with somewhat wavy contour forms the inner coat of the skin. The contents, according to T. F. Hanausek, are granules consisting sometimes of corroded crystals.

The Embryo (*C*) comprises two large cotyledons and a relatively small radicle.

1. *The Epidermal Cells* (*ep*) of the cotyledons are characterized by their elongated form and thick outer walls. Small aleurone grains are present in all the cells, and starch grains of small size, according to Hanausek, only in the guard cells of the stomata (*st*).

2. *Mesophyl.* Cells of large size containing aleurone grains (*al*), starch grains (*st*), and fat make up the larger part of the cotyledons. Their double walls, pierced by large pores, range up to 6 μ in thickness, being separated at the angles to form small intercellular spaces. The starch grains (up to 15 μ) are globular and have a central hilum. The aleurone grains vary greatly in shape and size, some of them being about the size of the largest starch grains, most of them, however, only half or a third as large. Several globoids are present in the largest grains.

DIAGNOSIS.

Peanut shells (pericarp) are a normal constituent of peanut cake made from unhulled peanuts and of cattle food made from damaged or immature fruits. They are identified by the pitted, more or less quadrilateral hypoderm cells (Fig. 224, *a*, *b*) and the various elements of the fiber layer, particularly the L- and T-shaped (*t*), toothed (*z*) and halberd-shaped (*h*) forms. The root hairs of the epidermis are difficult to find and the compressed parenchyma cells are not characteristic.

Products containing the seed include peanut cake, peanut confectionery, peanut butter (a paste prepared from the seed after removal of the pericarp and spermoderm), and the mixtures of chocolate and peanut cake prepared in Spain and possibly in other countries. The products contain not only the starch (Fig. 225, *st*), fat and proteids of the seed, but also in greater or less amount the tissues of the spermoderm (Fig. 226), of which the porous, sharply polygonal cells of the outer epidermis (*aep*), and the spongy parenchyma cells, often with narrow arms (p^3), are most useful in diagnosis. Fragments of the spermoderm, brown or red on the outer, yellow on the inner surface, can often be picked out under the single microscope.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Benecke (2); Böhmer (10); Hanausek, T. F. (48); Harz (18); Moeller (29); Vogl (45).

BILTERYST: Recherche de l'arachide et de son tourteau dans le chocolat. Jour. pharm. chim. 1897, **6**, 29.

KOBUS: Kraftfutter und seiner Verfälschung. Landw. Jahrb. 1884, **13**, 813.

UHLITZSCH: Rückstande der Erdnussölfabrikation. Landw. Vers.-Stat. 1892, **41**, 385.

WINTON: The Anatomy of the Peanut with Special Reference to its Microscopic Identification in Food Products. Conn. Agr. Exp. Sta. Rep. 1904, 191.

TONKA BEAN.

South America produces the larger part of the Tonka or Tonquin beans of commerce, the chief ports of shipment being Angostura in Venezuela, Surinam in Guiana, and Para in Brazil.

The true Tonka bean is the seed of *Coumarouna odorata* Aubl. (*Dipteryx odorata* Willd.), but less important commercial sorts are the products of other species of the same genus (*C. oppositifolia* (Aubl.) Taub., etc.). They are used in perfumery, flavoring extracts, and medicines.

As seen in the market, the black seeds vary from 25–50 mm. in length and from 10–20 mm. in breadth, measured across the flattened sides at the broadest part. One edge of the seed is sharp, the other blunt, the hilum being situated on the blunt edge near one end. The surface is wrinkled and often covered with white crystals of coumarin, the flavoring principle of this seed as well as of the leaves of sweet clover (*Melilotus officinalis*), sweet vernal grass (*Anthoxanthum odoratum*), and the sweet woodruff (*Asperula odorata*). Two large cotyledons with a small radicle at the end make up the embryo.

HISTOLOGY.

T. F. Hanausek has called attention to the histological structure of this seed, which shows some remarkable variations from the usual leguminous type.

Spermoderm. This, together with the perisperm and the nearly obliterated endosperm, separates from the embryo as a thin, brittle shell.

1. *The Palisade Cells* are much thinner-walled than in ordinary legumes, the cavity being broader than the double walls even in the outer portion where the walls are thickest. A nearly black substance fills the cavity. Seen in cross section, these cells are rectangular; in surface view, polygonal. The outer half of each cell is thickened by ribs arranged parallel to the axis and separated from each other by narrow slits or pores. Focusing on this outer portion of the cell, the thickened walls in surface

view appear beaded. The cells are 50–65 μ high and 16–25 μ broad. After maceration in alkali their characteristics are manifest.

2. *The Column Cells* have thickened walls and are not in close contact. Although hour-glass-shaped, the cells are often curiously distorted. They are 15–24 μ high, 30–50 μ broad.

3. *Spongy Parenchyma* with moderately thick walls and well marked intercellular spaces forms the third layer. In the inner layers the cells are much compressed.

4. *An Inner Epidermis* or pigment layer consists of transversely elongated cells with dark contents.

Perisperm. A layer of aleurone cells is classed by Hanausek as a nucellar remnant or perisperm.

Endosperm. Within the aleurone layer is a hyaline membrane with indistinct cellular structure, the remains of the endosperm.

Embryo. The isodiametric cells of the cotyledons contain round starch grains (4–9 μ) and yellow, irregularly elongated aleurone grains up to 35 μ long, embedded in a ground substance of fat and proteid material. As the aleurone grains are insoluble in water, both these and the starch grains are clearly differentiated by extracting sections with ether and mounting in potassium iodide iodine. Hanausek found that if the section was treated with alcohol before mounting in iodine solution, only a faint blue color appeared in the starch grains, a phenomenon which he attributed to the formation of a protective coat over the grains preventing the entrance of the iodine.

DIAGNOSIS.

Although synthetic coumarin has, to a large degree, replaced Tonka beans, the latter are still used in considerable amount in perfumery, snuff, and flavoring extracts. As vanilla extract is often mixed with extract of the Tonka bean, it is quite possible that ground vanilla beans are adulterated with ground Tonka beans.

Coumarin may be isolated and quantitatively determined by chemical means; but the microscope must be depended on to detect ground Tonka beans.

The palisade cells with dark contents, characteristic alike in section and surface view, the irregularly shaped column cells and the grains of aleurone and starch contained in the cotyledons, render identification a simple matter.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Hanausek, T. F. (48); Planchon et Collin (34); Vogl (44).

CAROB BEAN.

The nutritive elements of the carob bean (*Ceratonia Siliqua* L.) reside chiefly in the fleshy pods, which contain a high percentage of sugar. It is believed that the husks eaten by the prodigal son were the pods of this bean, then as now a common swine food; also that the locusts and wild honey on which John the Baptist subsisted while in the wilderness were respectively the seeds and pods of this same bean, hence the name St. John's bread.

Throughout the countries bordering on the Mediterranean the carob tree is cultivated and the pods are used as food for the poorer classes and cattle, also for the preparation of drugs, sirups, alcoholic liquors, etc. In Germany they are eaten by children as confectionery.

The several-seeded fruit is 10–20 cm. long, 2–3 cm. broad, 5–10 mm. thick, and has several cells with a coriaceous lining (endocarp), each containing a flattened, obovate seed 8–10 mm. long of a dark wine color. On either side of the furrowed sutures the pods are swollen, and within each of the four swollen portions occurs a row of cavities, which are readily seen in longitudinal section.

HISTOLOGY.

Pericarp (Fig. 227). Although this fruit is similar in structure to other legumes, several of the tissues have individual characteristics which allow of their ready identification.

1. *Epidermis* (*ep*). Of the several layers of cells with dark-brown contents which together form the leathery outer portion of the pod, the outermost consists of polygonal cells (12–30 μ) and stomata, with cuticularized outer walls.

2. *The Hypodermal Layer* (*rp*), often 120 μ thick, is made up of 6–10 layers of tabular parenchyma cells, which, in surface view, are rounded. They are filled with brown contents like that in the epicarp.

3. *Fibro-vascular Bundles*. The bast fibers (*b*) form a nearly uninterrupted layer. They are accompanied by crystal-fibers (*k*), each containing a single crystal, and stone cells (*st*). Further inward are the phloem and xylem, the latter containing only a few vascular elements.

4. *Mesocarp* (*mc*). The fruit-flesh or mesocarp is a thick tissue of large, thin-walled, radially elongated parenchyma cells, containing sugar and large, curiously wrinkled, reddish-brown lumps (*z*). These lumps are insoluble in water, alcohol, acetic acid, and dilute sulphuric

acid. Chlorzinc iodine colors them yellow, the cell-walls blue. A highly characteristic reaction is the colors produced by caustic soda or potash. If the alkali is cold and dilute, the color changes first to green, then to blue-gray. Heating produces a violet color. If, however, the alkali is strong and heat is cautiously applied, a magnificent deep blue is obtained at once. This color is insoluble in alcohol and ether,

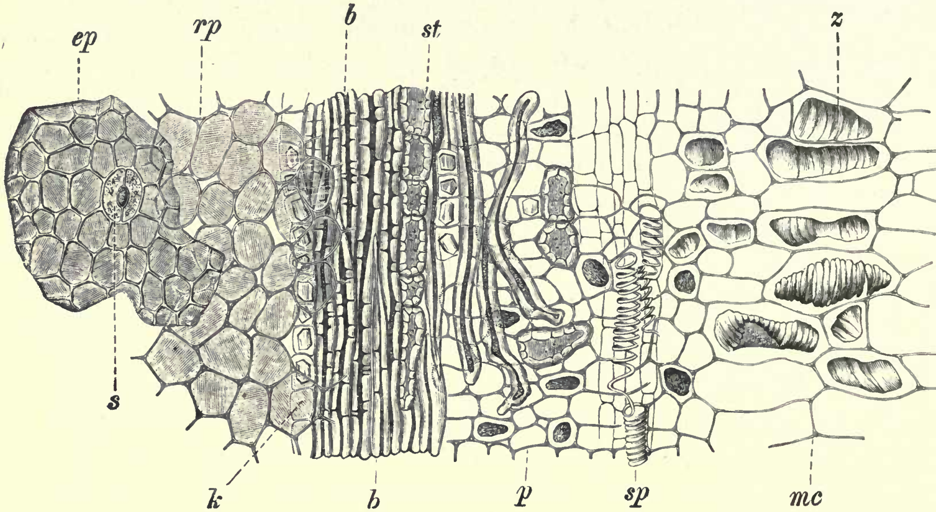


FIG. 227. Carob Bean (*Ceratonia Siliqua*). Elements of pericarp in surface view. *ep* epicarp with *s* stoma; *rp* brown hypoderm; *b* bast fibers; *mc* mesocarp with *z* wrinkled bodies. ×160. (MOELLER.)

but slowly changes on exposure to the air (more quickly with hydrochloric acid) to red-brown.

5. *Inner Fiber Layer.* The cavities containing the seeds have a chartaceous lining or "endocarp" consisting of bast fibers, crystal fibers, and stone cells, much like those occurring in the fibro-vascular bundles of the outer pericarp, also of an inner epidermis. The fibers in this layer are arranged transversely, in other words, at right angles to those of the outer pericarp.

6. *The Inner Epidermis* or *Endocarp* proper consists of a single layer of small, isodiametric cells (15–25 μ) with swollen and conspicuously beaded walls.

The Spermoderm is closely united with the endosperm.

1. *The Palisade Cells* examined in water are 170–250 μ high, of which 35–50 μ is a swollen outer layer with no evident lumens.

2. *Column Cells.* The walls of the hour-glass-shaped column cells

swell greatly, so that the cavities are hardly discernable. Intercellular spaces are, however, distinctly evident. The layer is 20–35 μ thick.

3. *Parenchyma.* The walls throughout are greatly swollen. In the outer and middle layers, the cells are large; in the inner layers small, and in addition dark colored.

The Endosperm (Fig. 228) is green-white, of a dense horny structure. In the middle of the broad side of the seeds it is 2 mm. thick, but diminishes toward the edges, where it is almost entirely absent. The partitions between the cells are enormously thickened, owing to a deposition of a carbohydrate material in the intercellular spaces. On heating with water this intercellular substance dissolves, while the swollen inner membrane or true cell-wall remains intact. Protein and fat are the only visible cell-contents.

FIG. 228. Carob Bean. Endosperm with thickened cell walls. (MOELLER.)

Embryo. In cross section the embryo appears as a narrow, yellow band less than 1 mm. thick, extending along the entire longer axis of the ellipse dividing the endosperm into two semielliptical halves.

Three inner layers of palisade cells and several outer layers of isodiametric cells form the mesophyl. The contents are aleurone grains and fat.

DIAGNOSIS.

Ground carob beans are used as a cattle food and a coffee substitute. The brown, wrinkled bodies (Fig. 227, *z*) of the mesocarp are identified by the blue color produced by heating with 5–10 per cent alkali. The bast fibers (*b*) and other elements of the bundles, also the cells of the epicarp (*ep*) and hypoderm (*rp*) with brown contents, are readily found, but are not characteristic. Of the seed elements, the long palisade cells with swollen outer walls, and especially the endosperm cells (Fig. 228), are most remarkable. The latter are best identified in sections cut from the white, horny fragments.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Bell (1); Harz (18); Moeller (29); Vogl (45).
MARLIÈRE: Sur la graine et spécialement sur l'endosperme du *Ceratonia Siliqua*. La Cellule, 1897, **13**, 5.

PART V.

NUTS.

NUTS.

PALM FRUITS (*Palmæ*).

The fruits of the palms are either fleshy (e.g. date) or dry (e. g. cocoanut). The endocarp of certain of these nuts is a thick layer of stone cells. The reserve material of the seed, consisting largely of fat and proteid (cocoanut, palm nut) or of cellulose in the form of thickened cell-walls (date, ivory nut), is usually stored in the endosperm.

COCOANUT.

The cocoanut palm (*Cocos nucifera* L.) yields food for man and cattle, oil, fiber, and other useful products, also adulterants.

The flowers are arranged in spikes branching from a central axis and inclosed with a tough spathe usually a meter or more in length. A single female flower is borne near the base of each lateral axis, and numerous male flowers are distributed on all sides of the axis between the female flower and the apex. After the male flowers drop, the naked lateral axis persists, forming a prominent appendage of the fruit (Fig. 229, *A*). Only one ovule of the three-celled ovary comes to maturity, but the tricarpellary nature of the fruit is indicated by its triangular shape as well as by the longitudinal ridges and the three eyes or germinating holes of the nut. When ripe the fruit is inverted pear-shape, 25 cm. or more in length.

The epicarp (Fig. 229, *Epi*) is a smooth tough coat, of a brownish or grayish color.

The mesocarp (*Mes*), consists of a thin, but hard outer coat, and a soft portion usually 3–4 cm. thick on the sides and much thicker on the base, with numerous longitudinally arranged fibers.

Oftentimes the inner layers of the mesocarp become impregnated with a brown fluid, which on drying gives the thin tissue a mottled brown appearance.

The endocarp, or shell (Fig. 229, *End*; Fig. 230), consists of a hard.

dark-brown coat, 2–6 mm. thick, with numerous fibers adhering to the surface. Three nearly equidistant ridges (often indistinct) pass from base to apex, where they unite to form a blunt point. At the basal end, between the ridges, are the three depressions or eyes (*K*), the tissues of which are much softer and thinner than those of the rest of the shell.

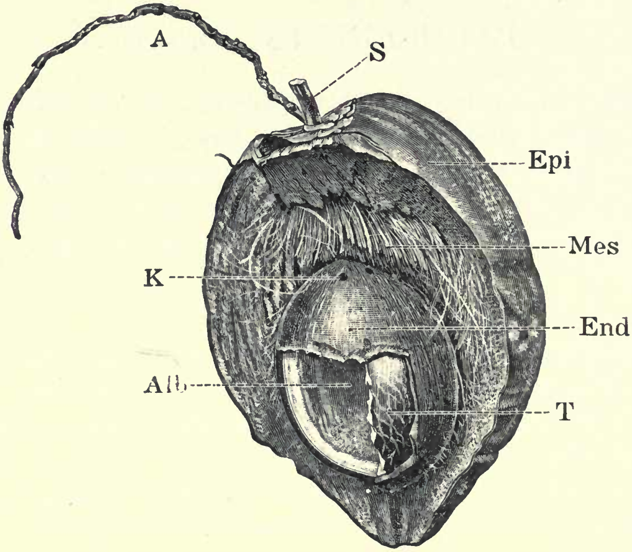


FIG. 229. Cocoanut (*Cocos nucifera*). *S* lower part of axis forming stem; *A* upper end of axis with scars of male flowers; *Epi* epicarp; *Mes* mesocarp with fibers; *End* endocarp or hard shell; *T* portion of spermoderm adhering to endosperm; *Alb* endosperm surrounding cavity of the nut; *K* germinating eye. ×⅕. (WINTON.)

Through the softest of these eyes the embryo, embedded in the endosperm directly behind it, escapes in sprouting.

The Spermoderm of the anatropous seed (*T*) is a thin coat of a light-brown color, closely united with the endocarp without and the endosperm within. Embedded in the outer portion and extending from the principal eye nearly to the apex is the raphe, consisting of a thin band of vascular tissues about 1 cm. broad, which sends off branches in all directions, forming a network about the seed. The endosperm with the inner portion of the spermoderm may be separated from the outer spermoderm and endocarp by introducing a knife-blade between the layers. By this operation the veins are split, part of the vascular tissue adhering to the convex surface of the inner spermoderm and the remainder to the concave surface of the outer spermoderm, so that both surfaces are covered with reticulations.

The endosperm or meat (*Alb.*) is a white, fleshy layer, 1–2 cm. thick, in which, near the base, is embedded the small embryo. While immature, the nut is filled with a milky liquid and has no solid endosperm, but as the ripening proceeds the endosperm is gradually formed and at the same time the milky liquid diminishes in quantity or entirely disappears.

FIG. 230. Cocoanut. Inner surface of shell with adhering outer spermoderm. At the left the raphe, from which proceed veins forming a network over the surface. $\times\frac{1}{5}$. (WINTON.)

The epicarp and mesocarp are cut away from nuts designed for export, although invariably a small amount of the mesocarp with its fibers remains attached to the shell. The dried meat (copra) is exported in large amount to Europe, where the oil is expressed.

HISTOLOGY.

Pericarp. 1. *The Epicarp* consists of a single layer of rectangular cells with dark contents.

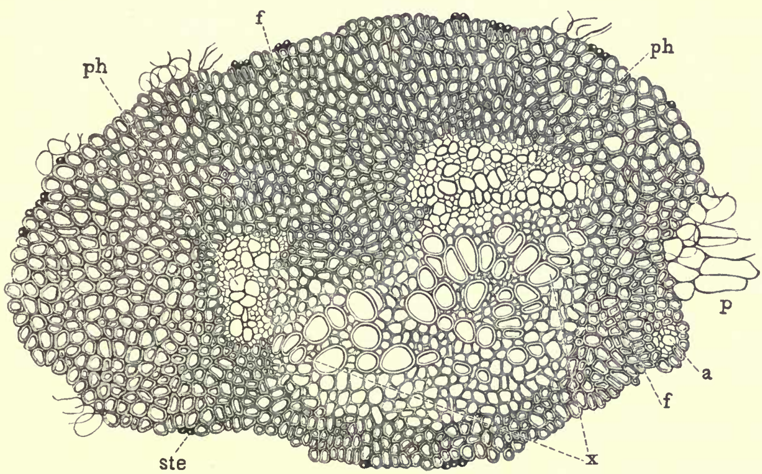


FIG. 231. Cocoanut. Cross section of a large flattened (mesocarp) fiber. *ste* stegmata; *f* sheath of bast fibers; *ph* two phloem groups; *x* xylem; *p* parenchyma of ground tissue; *a* rudimentary bundle belonging to small branch. $\times 90$. (WINTON.)

2. *Mesocarp.* The outer portion consists of a ground tissue of thick-walled, porous cells, through which pass longitudinally arranged strands

of bast elements. Further inward the ground tissue is thin-walled parenchyma and the strands are well developed fibro-vascular bundles. Wherever the brown liquid previously referred to has penetrated the

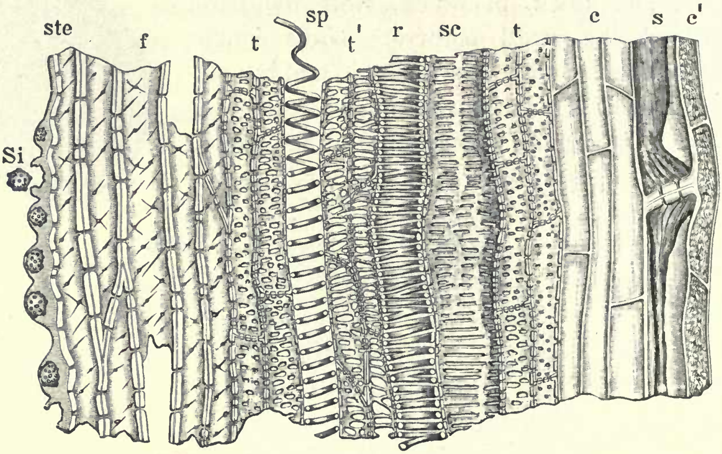


FIG. 232. Cocoanut. Longitudinal section of a large (mesocarp) fiber. *ste* stegmata; *Si* silicious body; *f* bast fibers; *t* tracheids with small pits; *t'* tracheids with large pits; *sp* spiral vessel; *r* reticulated vessel; *sc* scalariform vessel; *s* sieve tube; *c* and *c'* cambiform cells. ×300. (WINTON.)

inner layers of the mesocarp, groups of the parenchyma cells here and there, being impregnated with this material, are of a brown color and appear thicker-walled than the others (Fig. 234, *br*). This brown substance is quickly changed to a reddish color by alkali, but is not affected by alcohol, ether, or the specific reagents for proteids, fats and resins. No immediate effect is produced by ferric chloride solution, but on long standing the color is changed to olive-green.

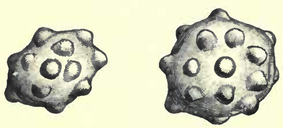


FIG. 233. Cocoanut. Silicious bodies from the stegmata of a fiber. ×1500. (WINTON.)

Coir fibers (Figs. 231 and 232) are built up of a thick sheath of bast fibers with rows of stegmata on the surface, and within the sheath two groups of phloem and one of xylem.

As seen in surface view the stegmata (*ste*) are circular or elliptical, thick-walled cells (8–20 μ) extending in longitudinal rows over the surface of the fibers. Inclosed in each cell and filling it almost completely is a silicious body (Fig. 233), 6–12 μ, with wart-like protuberances on the surface.

The phloem elements are sieve tubes and cambiform cells; the xylem elements, spiral, reticulated and scalariform vessels, also tracheids.

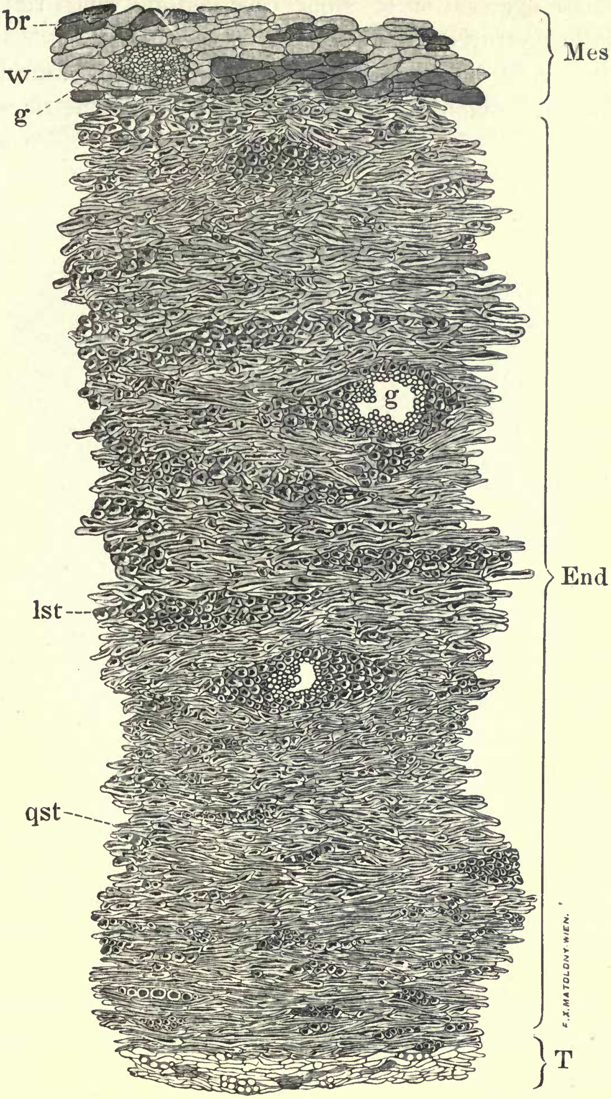


FIG. 234. Cocoanut. Cross section of shell. *End* endocarp or hard shell; *Mes* adhering mesocarp; *T* adhering outer spermoderm; *w* colorless parenchyma of mesocarp; *br* same as *w* but impregnated with a brown substance; *g* vascular bundles in the endocarp, with phloem and xylem partially obliterated; *lst* longitudinally elongated and isodiametric stone cells; *qst* transversely elongated stone cells. ×60. (WINTON.)

Endocarp (Figs. 234 and 235). This coat, known commonly as the shell, is a dense aggregation of stone cells, among which run longitudinally, partially destroyed bundles.

The stone cells have thick, deep yellow walls, branching pores, and dark-brown contents. They are either isodiametric or strongly

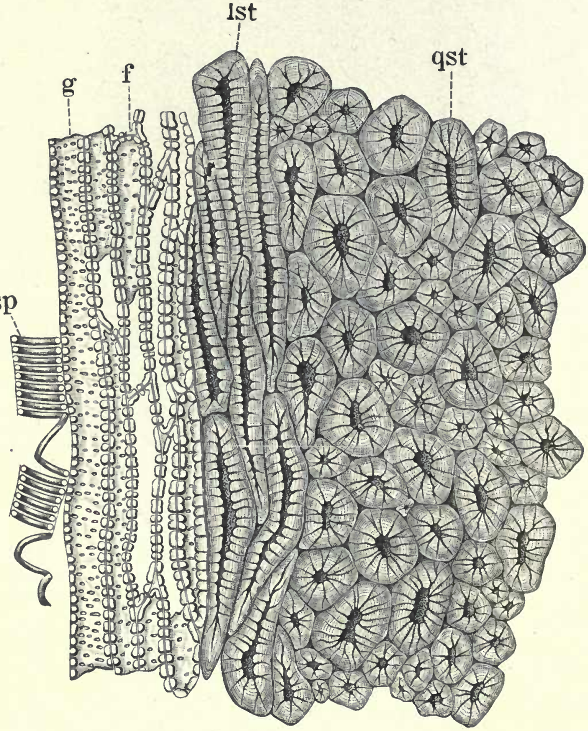


FIG. 235. Cocoanut. Longitudinal-radial section of shell (endocarp) through the stone cells and edge of bundle. *qst* transversely elongated and isodiametric stone cells; *lst* longitudinally elongated stone cells; *f* thick-walled porous cells; *g* pitted vessel; *sp* spiral vessel. ×300. (WINTON.)

elongated. The latter (often 20 μ long) are usually spindle- or wedge-shaped, although hammer-shaped, hooked and various other curious forms abound.

They are arranged in groups, commonly with the longer diameters in tangential transverse directions and are best seen in cross sections of the shell (*qst*), but in some groups, particularly those adjoining the bundles, they pass longitudinally about the shell (*lst*).

Groups of thinner-walled cells with dark-brown contents are occasionally met with.

The brown contents of all the endocarp cells react the same as the brown impregnating material of the mesocarp.

Vascular bundles (Fig. 234, *g*; Fig. 235) are studied with difficulty in the mature shell. By the rupture of the phloem and part of the xylem during growth, passages are formed, which, in shells transversely cut or broken, are evident to the naked eye as minute holes. The structure

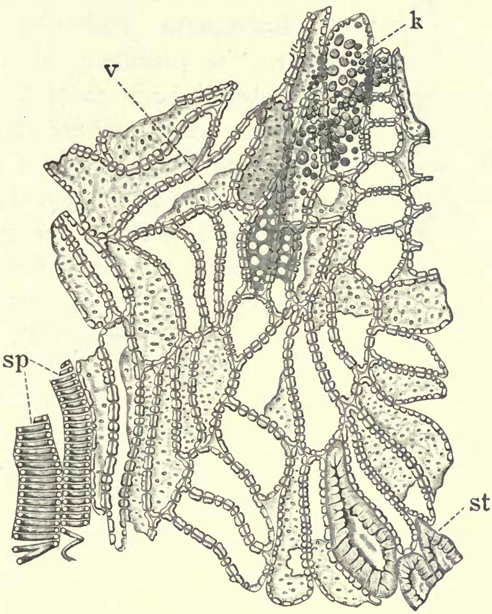


FIG. 236. Cocoanut. Tangential section of outer spermoderm showing ground tissue of thick-walled porous cells. Most of these are empty, but a few contain brown contents in the form of *k* globules, or *v* films with circular openings. *st* colorless stone cells; *sp* spiral trachea. ×300. (WINTON.)

of the bundles is still further obscured by the presence of fungus threads and spores.

In structure the bundles differ from those of the mesocarp fibers, the bast fibers being replaced by forms (*f*) intermediate between these and tracheids. The vascular elements are chiefly spiral vessels (*sp*), and pitted vessels (*g*), the latter being especially noticeable.

Spermoderm. 1. *Outer Layers.* This coat consists of a ground tissue of large, variously shaped cells, crossing one another in all directions (Fig. 236), between which ramify the veins.

2. *Inner Layers.* Firmly attached to the endosperm are from ten to twenty layers of small isodiametric or slightly elongated cells. The

double walls are about 3 μ thick and free from pores. These cells contain a material varying in color from light yellow to dark brown, which either fills them completely or occurs in globules, films, etc., as in some of the cells of the outer spermoderm. In the layer adjoining the endosperm the cells are smaller and have darker brown contents than the cells in the other layers.

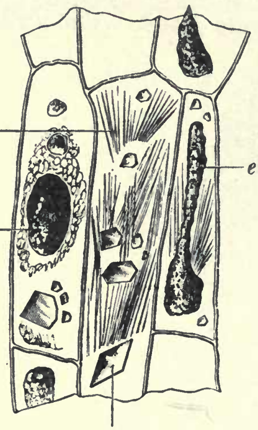


FIG. 237. Cocoanut. Cross section of endosperm in glycerine. *al* aleurone grain; *kr* crystalloid; *fk* fat crystals; *ei* oil plasma. (T. F. HANAUSEK.)

Endosperm (Fig. 237). In the outer layers, the prismatic cells are nearly isodiametric (about 50 μ in diameter), but further inward they are radially elongated, often reaching a length of 300 μ. Double cell-walls are about 3 μ thick. According to T. F. Hanausek, the radial walls are non-porous; the tangential walls, however, show large, but indistinct pores, which are evident after heating with water or treatment with alkali. The cell-contents are bundles of needle-shaped fat crystals, and aleurone grains, each grain usually containing a large crystalloid, sometimes 25 μ in diameter. Ether and alcohol readily dissolve the fat crystals and strong alkali saponifies them. The aleurone grains give the usual color reactions with iodine, Millon's reagent, and dyes.

DIAGNOSIS.

Shredded Cocoanut is the desiccated flesh of the cocoanut reduced to a coarse powder. It is sold in packages for use in making pastries and confectionery.

The microscopic elements are the thin-walled cells (Fig. 237) of the endosperm, containing large aleurone grains and fat, also occasional fragments of the spermoderm.

Cocoanut Cake, the residue from the manufacture of cocoanut oil, is in Europe a well-known cattle food and adulterant of spices, but is almost unknown in the United States. The cells of the endosperm are distinguished from those of the palm nut by their thinner walls; the contents of large aleurone grains and fat are, however, much the same in the two species. Of no little value in diagnosis are the tissues of the spermoderm, especially the porous, moderately thick-walled elements of the outer layers.

Cocoanut Shells. It is stated on credible authority that in a certain American city several hundred tons of shells, obtained as a by-product in the preparation of shredded cocoanut are annually reduced to a powder in mills of peculiar construction and sold to spice grinders. This powder, without further treatment, is mixed with ground allspice, which it closely resembles in appearance. By cautious roasting the color of ground cloves and nutmegs is matched, and by roasting at a higher temperature a charcoal is obtained which, mixed with starchy matter, is a clever imitation of black pepper.

Powdered cocoanut shells appear to be a distinctively American adulterant, while cocoanut cake, which in Europe is commonly employed both as a cattle food and as an adulterant of human foods, is almost unknown in America.

All the tissue elements of the mesocarp, the endocarp and the outer spermoderm are present in cocoanut shell powder (Fig. 238), but the stone cells (*st*) of the endocarp make up the bulk of the material. These stone cells are characterized by their brown-yellow walls, their dark-brown contents becoming red-brown on treatment with alkali, and the predominance of peculiar elongated forms. They differ in one or more of these characteristics from the stone cells of pepper, allspice, clove stems, walnut shells, almond shells, Brazil-nut shells, hazelnut shells, peach stones and olive stones.

The outer spermoderm or lining of the shell also forms a considerable part of the powder, the most striking elements being the thick-walled porous cells (*p*) and the vascular elements.

Colorless cells of the mesocarp ground tissue (*w*) are not distinguishable from the parenchyma of many other plants, but when impregnated with the brown substance which has been described they are striking objects (*br*). Alkali changes the color of these brown cells to a reddish brown, but ferric chloride does not produce any immediate effect, thus distinguishing them from the brown cells of allspice seed, the color of which alkali removes and ferric chloride changes at once to a green.

Spiral, reticulated, and pitted vessels (*sp*, *t*, and *g*), from the mesocarp, endocarp, and spermoderm bundles, are also frequently met with in the powder, the pitted vessels being quite unlike any vascular elements of the spices.

The stegmata (*ste*) of the mesocarp fibers with their silicious contents are characteristic, but they are difficult to find owing to the great

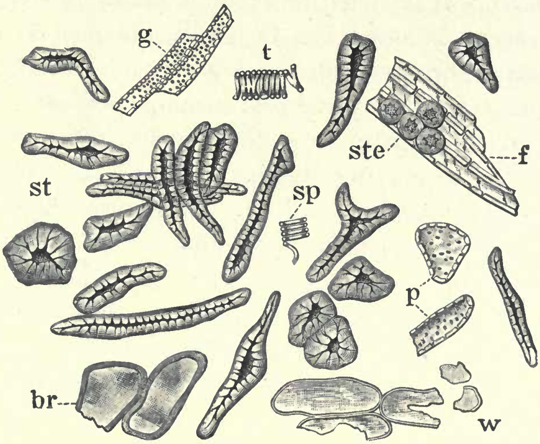


FIG. 238. Cocoanut shell. Elements in powder form. *st* dark-yellow stone cells with brown contents; *t* reticulated vessel; *sp* spiral vessel; *g* pitted vessel; *w* colorless, and *br* brown parenchyma of mesocarp; *f* bast fibers with *ste* stegmata. ×160. (WINTON.)

preponderance of other tissues. Bast fibers (*f*) are more liable to be encountered than stegmata, but they furnish less conclusive evidence.

Spices adulterated with charred cocoanut shells show under the microscope black, opaque fragments which are not bleached by aqua regia, or nitric acid and potassium chlorate. Except in cases where some of the stone cells or other elements have escaped charring, this material cannot be distinguished from other forms of charcoal.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Benecke (2); Böhmer, (6, 10, 23); Collin et Perrot (9); Hanausek, T. F. (16, 17, 48); Harz (18); Moeller (29); Planchon et Collin (34); Vogl (45).

MOELLER: Die Rohstoffe des Tischler- und Drechslergewerbes. Cassel. 1884.

WINTON: The Anatomy of the Fruit of *Cocos nucifera*. Amer. Jour. Sci. 1901, **12**, 265. Conn. Agr. Exp. Sta. Rep. 1901, 208. Amer. Jour. Pharm. 1901, **73**, 523.

PALM-NUT.

Closely related to the cocoanut, although differing greatly from it in macroscopic appearance, is the drupaceous fruit of the oil-palm (*Elaeis Guineensis* L.).

The palm fruit is about the size of a date and has a deep-red, oily fruit flesh or mesocarp, and a hard endocarp. Within the thin, brown spermoderm is a blue-gray endosperm containing a minute embryo, and within the endosperm is a small cleft corresponding to the large cavity of the cocoanut.

Palm oil is expressed from the seed, which has previously been freed from the mesocarp and the greater part of the endocarp.

HISTOLOGY.

After shelling, a few stone cells of the endocarp often remain attached to the spermoderm. These, in surface view, are polygonal with distinct pores.

The Spermoderm (Fig. 239, *s*) is composed of several layers of thin-walled, tangentially elongated cells, those in one layer often crossing those of the adjoining layer. The outer cells contain a brown substance, the inner, a material which, according to T. F. Hanausek, becomes lemon-yellow with alkali.

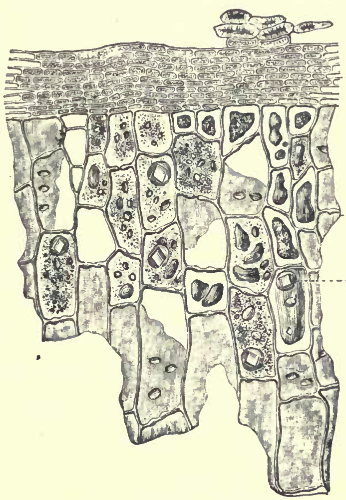


Fig. 239. Palm-nut (*Elaeis Guineensis*). Outer portion of seed in cross section. *s* spermoderm; *E* endosperm containing *a* aleurone grains. ×160. (Moeller.)

The Endosperm (Fig. 239, *E*) of the palm-nut is distinguished from that of the cocoanut by the thicker walls (double 5 μ) and more distinct pores, the walls, in section, having a knotty appearance. As a rule, the cells are radially elongated. Masses of fat crystals and aleurone grains are the most conspicuous cell-contents. T. F. Hanausek states that crystals of fatty acids grouped in bundles are also present. Globular aleurone grains (*a*), each containing a large crystalloid, may be seen in water or glycerine mounts, but are best studied after successive treatment with tincture of iodine and very dilute hydrochloric acid. This latter procedure, recommended by Hanausek, colors the grains yellow, the brilliant crystalloid being clearly seen through the transparent proteid envelope. In the inner layers, the aleurone grains are often 25 μ in diameter, in the outer layers, much smaller.

DIAGNOSIS.

Palm Cake and the meal prepared from it is imported from Africa into Europe for cattle feeding. It is also much used as an adulterant of pepper.

This product is distinguished from cocoanut cake by the distinctly porous, knotty-thickened walls of the endosperm (Fig. 239, *E*). Tissues of the spermoderm (*s*) and endocarp are also of service in identification.

The aleurone grains (*a*), fat masses, and bundles of raphides, which make up the bulk of the material, are rendered distinct by treatment with iodine tincture followed by dilute hydrochloric acid.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Benecke (2); Böhmer (6, 10, 23); Collin (8); Hanausek, T. F. (10, 16, 17, 48); Harz (18); Moeller (29); Schimper (37); Villiers et Collin (42); Vogl (45).

EMMERLING: Ueber Palmkernkuchen und mehl. Landw. Vers.-Stat. 1898, **50**, 5.

HANAUSEK, T. F.: Ueber die Frucht der Oelpalme. Ztschr. allgem. österr. Apoth.-Ver. 1882, **15**, 325.

KOBUS: Kraftfutter und seine Verfälschung. Landw. Jahrb. 1884, **13**, 813.

MEYER, A.: Ueber die Oelpalme. Arch. Pharm. 1884, **22**, 713.

MOELLER: Ueber afrikanische Oelsamen. Dingl. polyt. Jour. 1880, **238**, 252.

WAX-PALM.

The seed of the wax-palm (*Corypha cerifera* L., *Copernica cerifera* Mart.) for a long time has been used in Brazil as a coffee substitute and in recent years has been introduced into Europe.

The seed, similar in size and shape to a small acorn, is of a light-brown color with irregular, dark-brown, longitudinal striations. The inner surface of the spermoderm and the adhering outer surface of the endosperm are deeply wrinkled. A small embryo is embedded in the endosperm at the base of the seed near the hilum.

HISTOLOGY.

The Spermoderm consists of: (1) two or more layers of small, thin-walled, polygonal cells; (2) several layers of large, isodiametric or slightly elongated, rounded, sclerenchyma cells with moderately thick, porous walls, and numerous intercellular spaces; and (3) a thick tissue of parenchymatous elements.

Endosperm. As regards the structure of the endosperm, the seeds belong in the same class with the coffee bean, the ivory-nut, the date stone and other seeds with carbohydrate reserve material largely in the form of cellulose. The cell-walls are porous, somewhat thinner than those of the date endosperm.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Villiers et Collin (42); see also Bibliography of Coffee: Brunotte; König.

IVORY-NUT.

Several species of the genus *Phytelephas*, of which *P. macrocarpa* R. et P. is the most important, yield the true ivory-nuts or vegetable ivory used in making buttons and other articles. The sawdust and similar refuse, after being roasted, has been mixed with coffee and possibly other ground food products.

The true ivory-nut, as it appears in commerce, is of about the size of a hen's egg, but is shaped more like a segment of an orange. It consists of a brittle shell (the inner pericarp), gray on the surface, but dark within, and inclosed in this a large seed with a thin, brown spermoderm. The endocarp and seed are grown together during the earlier stages of development, but when fully ripe, the endosperm together with most of the spermoderm shrinks away from the endocarp and becomes loose in the cavity. On the surface of the loose seed may be seen the raphe and its numerous branches, also near the hilum, a wart-like protuberance beneath which is a small cavity containing the germ.

HISTOLOGY.

Pericarp. Three layers of the pericarp form the shell.

1. *The Outer Layer* is made up of several layers of thickly porous, colorless cells arranged in radial rows like cork cells.

2. *Palisade Cells.* These remarkable cells, brought to notice by Molisch, are 500 μ high and 40–90 μ broad, with thickened inner and side walls of a dark-brown color. The side walls diminish in thickness toward the top, the cavity being as a consequence funnel-shaped. What is most remarkable of all is the presence in each cell of a silicous body entirely filling the cavity. These bodies may be clearly seen after reducing sections to an ash and dissolving out other mineral matter with hydrochloric acid.

3. *Collapsed Cells* form a thin layer beneath the palisade cells.

Spermoderm (Fig. 240, *S*). 1. *Sclerenchyma Fibers* with dark contents, crossing one another in the different layers, form the outer coat.

The separation of the pericarp from the seed takes place in the layer through which ramify the raphe and its branches, the outer portion of the spermoderm remaining attached to the inner surface of the pericarp.

2. *Inner Layers.* Large, nearly isodiametric cells with thick walls, but without evident pores, complete the spermoderm. These are shown at the left in Fig. 241.

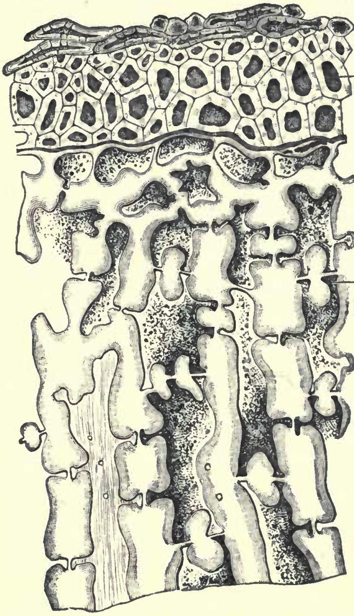


FIG. 240. Ivory-nut (*Phytelephas macrocarpa*). Cross section of outer layers. *S* spermoderm; *E* endosperm with thickened cell walls. (MOELLER.)

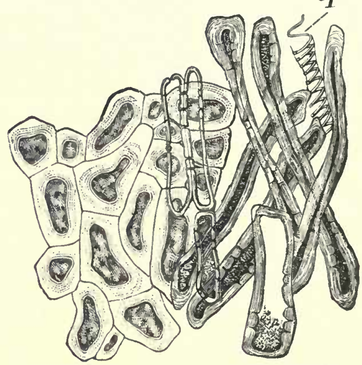


FIG. 241. Ivory-nut. Elements of spermoderm. ×160. (MOELLER.)

The Endosperm (Fig. 240, *E*) of the ivory-nut is the most striking of all the examples of reserve material in the form of cellulose. The cell-walls are on the average about 35 μ thick and often exceed 50 μ. Penetrating these walls are conspicuous pores, which broaden at the middle lamella. Most of the cells are radially elongated.

DIAGNOSIS.

Ivory-nut powder, a material used as an adulterant of coffee, is identified by the enormously thickened cell-walls of the endosperm (Fig. 240), also by the tissues of the spermoderm (Fig. 241) and pericarp. The only materials with which it might be confounded are ground date stones and Polynesian ivory-nuts. The date stone seldom has cell-walls as thick as those in the ivory-nut, furthermore, the tissues of the spermoderm are different.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Böhmer (23); Hanausek, T. F. (16, 17, 48); Moeller (29); Planchon et Collin (34); Vogl (45).

HANAUSEK, T. F.: Ueber einige, gegenwärtig im Wiener Handel vorkommende Gewürzfälschungen. Ztschr. Nahr.-Unters. Hyg. 1894, 8, 95.

MOLISCH: Die Kieselzellen in der Steinschale der Steinnuss. Centr.-Org. Waarenk. Techn. 1891, 103.

MOELLER: Die Rohstoffe des Tischler- und Drechslergewerbes. Cassel, 1884.

POLYNESIAN IVORY-NUT.

Of late years, seeds of several species of *Coclococcus* known as Polynesian or Tahiti ivory-nuts have been substituted for true ivory-nuts, and their by-products, quite probably, have been utilized for adulterating foods.

T. F. Hanausek finds that these seeds differ from true ivory-nuts in having: (1) longer but narrower endosperm cells; (2) more conspicuous middle lamellæ; (3) diagonal markings on the cell-walls as seen in section; and last but most important, crystals of calcium oxalate as cell-contents.

BIBLIOGRAPHY.

HANAUSEK, T. F.: Zur Anatomie der Tahitinuss. Ztschr. allgem. österr. Apoth.-Ver., 1880, **13**, 360. Ztschr. Nahr.-Unters. Hyg. 1893, **7**, 197.

WALNUTS (*Juglandaceæ*).

The fruits are 2–4 celled, with a rather thick, leathery mesocarp and a hard, 2–4 celled endocarp or nut shell. The seed consists largely of a curiously furrowed embryo with reserve material in the form of fat and proteid matter. The endocarp is made up of a dense mass of colorless stone cells. Characteristic of the spermoderm are the large stomata.

EUROPEAN WALNUT.

The walnut tree (*Juglans regia* L.), a native of Asia, is extensively cultivated throughout the central and southern regions of Europe, particularly in France, Italy, Spain, and Greece, also within the past few years in California. As European nuts reach America by way of England they are known there as English walnuts.

Inclosed by the husk, the fruit is usually 4–8 cm. long and about two-thirds as broad. When dry the epicarp and strongly scented mesocarp separate from the nut proper, consisting of the shell or endocarp and the seed. The nut is light brown, ovoid, short-pointed, and marked on the surface by shallow furrows and depressions. Encircling it longitudinally is a suture, into which a knife-blade may be easily inserted, thus separating the shell into two equal segments. Thin partitions divide the cavity imperfectly into four cells at the base and two at the top. The curiously wrinkled and lobed orthotropous seed, conforming in shape to the embryo, is covered with a thin, brownish-yellow skin or spermoderm. The embryo has two large cotyledons arranged at right angles to a plane passing through the suture and partially separated from each other by a thin partition; each cotyledon is deeply lobed, the lobes being separated by another partition at right angles to the first. The relatively small, pointed radicle is directed upward.

HISTOLOGY.

Only the endocarp and seed need be studied, as the epicarp and mesocarp are removed before the nuts are marketed.

Pericarp. Sect ons of the shell are cut with a strong blade or are obtained by grinding on an oil stone (p. 13).

1. *The Outer Endocarp* (Fig. 242), the hardest part of the shell, is a dense aggregate of nearly isodiametric cells with almost colorless walls so strongly thickened that the lumen is scarcely evident.

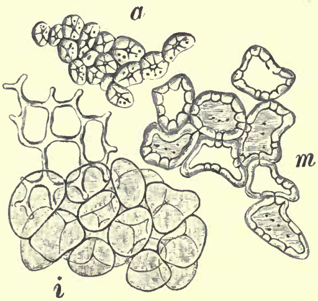


FIG. 242. Walnut (*Juglans regia*). Tissues of shell. *a* stone cells of outer layer; *m* stone cells of middle layer; *i* parenchyma of inner layer. ×160. (MOELLER.)

2. *Middle Endocarp* (*m*). The cells increase in size and the walls diminish in thickness in the middle layers, the thickness of the walls in most of the cells being much less than the breadth of the lumen. Many of the cells have irregularly concave faces, a peculiarity noticeable even in powdered shells.

3. *The Inner Endocarp* (*i*) is a loose parenchyma with thin, brownish walls becoming darker on addition of alkali.

Spermoderm. The seed may be easily sectioned without special preparation. The cell structure should be studied after treatment with Javelle water and staining; the aleurone grains, in sections mounted directly in turpentine or, after extraction with ether, in glycerine.

1. *Outer Epidermis.* As may be seen in cross section, the thin-walled, prismatic cells, containing yellow or brown material, are more or less radially elongated, and often divided by tangential partitions. In surface view they are sharply polygonal. The large stomata, often broader than long, are very noticeable.

2. *The Middle Layers* are composed of compressed yellow-brown cells which do not usually assume their original form on treatment with Javelle water.

3. *Inner Epidermis.* The cells of this layer are also compressed, but on soaking in Javelle water swell to their original form.

Perisperm. The hyaline membrane, forming what appears to be the thickened outer wall of the endosperm, is probably the remains of the perisperm.

Endosperm. The outer cell layer of the seed flesh, although usually firmly attached to the second layer, is sharply differentiated from the latter, the two layers being separated by a thick membrane. This outer layer is endosperm. Seen in surface view, the polygonal cells are 15–40 μ in diameter and have thick walls. They resemble the aleurone cells of cereals.

Embryo. The cells are of the usual thin-walled parenchymatous type and contain irregular aleurone grains up to 10 μ in diameter, also oil globules.

DIAGNOSIS.

The Seeds or "meats" are largely used in foods, either whole or chopped. The residue from the manufacture of walnut oil is obtained in limited amount in Europe and is utilized as a cattle food.

The most conspicuous elements are the polygonal outer epidermal cells of the spermoderm and the broad stomata.

Ground Walnut Shells are in Europe a common adulterant of spices. The elements are of three forms: (1) the small but thick-walled, colorless stone cells (Fig. 242, *a*) of the outer layers; (2) the colorless stone cells (*m*) of the middle layers, characterized by their large size, broad lumen, and irregular, here and there concave, outline; (3) the loosely united cells (*i*) of the inner layers, with thin, yellow or brown walls.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Böhmer (23); Collin et Perrot (9); Hanausek, T. F. (10, 16); Macé (26); Moeller (29); Villiers et Collin (42); Vogl (45).

GODFRIN: Étude histologique sur les tégument séminaux des Angiospermes. Soc. d. Sci. d. Nancy. 1880, 109.

HARTWICH: Ueber die Fruchtschale von *Juglans regia.* Arch. d. Pharm., 1887, **25**, 325.

PFISTER: Wallnusskuchen. Landw. Vers.-Stat. 1894, **43**, 448.

BLACK WALNUT.

The black walnut tree (*Juglans nigra* L.), a native of America, is valuable chiefly for its wood. The globular nut is about the same size and shape as the European walnut, but has an exceedingly rough endocarp with deep furrows and numerous sharp, branching ridges.

Notwithstanding these differences, the two nuts have much the same microscopic structure. The aleurone grains are somewhat smaller in the American species, but the difference is too slight to be decisive.

The nut is seldom found on the market.

BUTTERNUT.

This American nut, the fruit of *Juglans cinerea* L., differs from the black walnut chiefly in being elongated, and sharply pointed at both ends. The structure of the two is practically the same.

PECAN NUT.

One of the most valuable native nuts of the United States, is the pecan nut (*Carya olivaeformis* Nutt.), produced by wild and cultivated trees in the central and central southern states.

The nut is smooth, elongated, 3–4 cm. long, taper-pointed, and very indistinctly six-ribbed. It is divided at the base into two cells. Although small, the meats have a mild, delicious flavor, and are much used in confectionery, while the shells are available for adulterating spices.

In structure both the seed and shell are much like those of the English walnut. The aleurone grains are, however, somewhat smaller, seldom exceeding 6 μ in diameter.

HICKORY-NUT.

In addition to the pecan tree, various others of the same genus yield edible nuts, of which the shellbark or shagbark hickory-nut, (*C. alba* Nutt.) is the most valuable, and is the only one gathered in considerable amount for the market. The somewhat flattened nut of this species is about 3 cm. long and nearly as broad, the light colored, more or less angular but otherwise smooth surface, being marked with six indistinct ribs ending abruptly in a sharp point at the apex.

The structure of the hickory-nut is the same as that of the pecan nut.

CUP NUTS (*Cupuliferæ*).

These nuts are usually borne in an involucre or cup. The pericarp is horny or leathery, with stone cell layers. The single seed consists largely of embryo, which is either starchy (acorn, chestnut) or fatty (beech-nut, hazelnut). The hairs of the pericarp and spermoderm are often of service in diagnosis, as are also the starch grains of the two species named.

CHESTNUT.

The European or Spanish chestnut (*Castanea sativa* Mill.), the American variety (*C. sativa* var. *Americana* Michx.), and the Japanese chestnut (*C. crenata* Sieb. et Zucc.) are all forest trees of great value, not only for their timber but for their edible nuts. In Spain, southern France, Italy, and other countries bordering on the Mediterranean, chestnuts form a staple article of diet with the poorer classes, while in other European countries and in America they are regarded more as delicacies.

Spanish and Japanese chestnuts are large, 2.5 cm. or more broad, whereas those of the American variety are only 1.5–2.5 cm. broad. Commonly 2–3, rarely 4–7, nuts are enclosed within a densely spiny involucre or burr which does not open until the nuts reach full maturity. The outer nuts in the burr are plano-convex, the inner flattened on both sides. At the base they are broad and rounded, at the apex pointed with more or less of the style attached. The dark brown, leathery pericarp is smooth and glossy, except on the broad scar at the base, where it is dull and lusterless, and near the point, where it is hairy. On the inner surface it is covered with a dense mat of silky hairs. The thin, brown spermoderm separating readily from the seed, is sparingly pubescent on the outer surface, but on the inner surface is smooth, although marked by irregular ribs corresponding to the furrows on the surface of the cotyledons. The flesh of the large cotyledons is starchy, and when dry is readily reduced to a powder. It has a sweet taste.

HISTOLOGY.

Fresh or dried nuts of either the Spanish or American chestnut may be used for laboratory work.

Pericarp. Transverse sections, also tangential sections at different depths may be cut with a strong razor and examined both with and without treatment with alkali.

1. *Epicarp.* The cells are polygonal or quadrilateral, either isodiametric or longitudinally elongated, in the latter case often arranged end to end in irregular rows. Their contents are of a deep-brown color. Hairs are present at maturity only about the apex, although hair scars are found on other parts. They are pointed or rather blunt, 2–3 mm. long, and vary greatly in breadth and wall-thickness. The breadth of the lumen in the larger hairs is greater than the thickness of the walls, but in the case of the smaller hairs the reverse is often true.

2. *Sclerenchyma.* The cells of the outer layers, as appears from cross sections, are radially elongated, often 50 μ high, and have thick walls. In tangential section they are either isodiametric or longitudinally elongated, the walls being deeply sinuous and much folded, reminding us of the intestine cells of capsicum. Their shorter diameter is usually over 25 μ. In the middle layers the cells are smaller than in the outer, have relatively thicker walls, and are polygonal in outline; while in the inner layers large cells with broad lumen predominate. The structure of the tissues beneath the scar varies somewhat from those described and many of the cells contain large oxalate crystals.

3. *Mesocarp.* Longitudinally elongated, more or less quadrilateral cells with very thick, beaded walls form the middle layers of the pericarp. The cell-contents are colored brown and the cell-walls yellow-brown. Intercellular spaces frequently occur at the corners of the cells and between the side walls. Fibro-vascular bundles with strongly developed bast tissues run through the mesocarp.

4. *Endocarp.* This layer is itself inconspicuous owing to the dense mat of hairs forming the woolly lining of the pericarp. The hairs vary

up to several millimeters in length and up to 35 μ in breadth. They are pointed, often crooked, and have broad lumen and very thin walls.

Spermoderm. This coat may be separated from the seed as a papery brown membrane.

1. *The Outer Epidermis* consists of polygonal cells up to 50 μ in diameter, interspersed with hairs similar to those on the endocarp.

2. *Middle Layer.* The loose tissue of brown cells traversed by fibro-vascular bundles is of little interest.

3. *An Inner Epidermis* of polygonal cells without hairs completes the spermoderm.

Embryo. The parenchymatous tissue of the cotyledons contains numerous starch grains (Fig. 243) up to ·30 μ in diameter. Among the large grains are ovoid, pear-shaped, fusiform, rounded triangular, polygonal, and various irregular forms, often with wart-like excrescences. The hilum is commonly eccentric, indistinct, and may or may not have radiating clefts. With suitable illumination, rings are clearly evident.

DIAGNOSIS.

Chestnut Meal is a food product of considerable importance in southern Europe, where it is made into puddings, cakes, and even into bread. Starch (Fig. 243) is the predominating element. The large grains are

FIG. 243. Chestnut Starch (*Castanea vesca*). ×600. (MOELLER.)

less than 30 μ in diameter, and are of the various irregular forms already noted, with inconspicuous, eccentric hilum. Hairs from the pericarp or spermoderm, like those of the acorn, beech-nut, and hazelnut, are remarkable for their thin walls and broad lumen.

Chestnut Shells are characterized by the thin-walled hairs, the sclerenchyma cells with thick, sinuous walls, and the thick-walled, beaded mesocarp.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Hanausek, T. F. (16); Harz (18); Vogl (45); Wiesner (48).

GODFRIN: Étude histologique sur les tégument séminaux des Angiospermes. Soc. d. Sci. d. Nancy. 1880, 109.

HANAUSEK, T. F.: Zur mikroskopischen Charakteristik des Kastanienmehles. Beilage der Ztschr. f. Landw. Gewerbe. Dobruska, 1883, No. 1, 3.

ACORN.

Several European species of oak, notably *Quercus Cerris* L., *Q. pedunculata* Ehrh., *Q. sessiliflora* Salisb., and *Q. pubescens* Willd., yield edible acorns, the kernels of which are used chiefly for making a substitute for coffee known as acorn coffee. In America, acorns are produced in large quantities by numerous native species and are eaten on the ground by swine, but as yet are not gathered for the market.

Whatever the species producing it, the acorn is characterized by its well-known form, the short wart at the apex, its smooth surface, and the circular scar at the base. The cup-shaped, scaly involucre (the cupule) in some species is shallow, in others deep, nearly covering the acorn. The pericarp is made up of a hard outer coat and soft inner tissues of a deep brown color, the innermost layer or endocarp being either smooth or densely woolly. A thin, brown spermoderm incloses the embryo, the latter consisting of two large fleshy cotyledons and a small radicle. Endosperm is lacking.

HISTOLOGY.[1]

The structure of acorns of different species is very similar, the chief differences being in the presence or absence of hairs on the endocarp and the size of the starch grains.

Cupule. 1. *The Outer Epidermis* consists of polygonal cells averaging 14 μ in diameter interspersed with numerous pointed hairs varying up to 700 μ in length. In the inner half of each hair the lumen is broad,

[1] Free use has been made of the descriptions of Mitlacher, who has studied the cupule, pericarp, and spermoderm of *Quercus sessiliflora*.

but toward the apex it is reduced to a narrow line. At the base the hairs are somewhat constricted owing to pressure of adjoining cells.

2. *Middle Layers.* In a ground tissue of thin- or moderately thick-walled chlorophyl parenchyma are distributed numerous stone cells occurring either singly or in small groups. These cells vary in form and are usually between 100 and 200 μ in diameter. The solitary cells have thinner walls than those in groups and often contain crystal clusters of calcium oxalate. The bicollateral bundles are accompanied on the outer side by sclerenchyma fibers and rows of crystal chambers.

3. *The Inner Epidermis* is much like the outer in structure.

Pericarp. 1. *The Epicarp* (Fig. 244, *epi*; Fig. 245) on the lower part of the fruit is made up of cubical cells regularly arranged in rows, form-

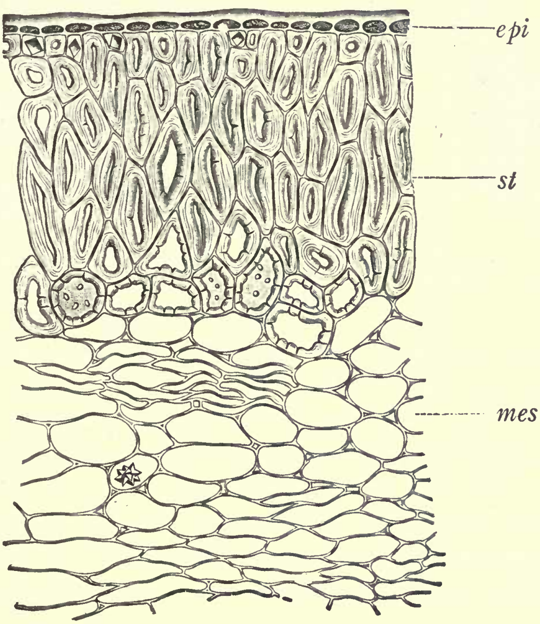


FIG. 244. Acorn (*Quercus sp.*). Tissues of shell in cross section. *epi* epicarp; *st* crystal cells and stone cells; *mes* mesocarp. (MOELLER.)

ing a highly characteristic tissue. These cells contain colorless drops in a brown ground substance. On the upper end in many species are numerous hairs (Fig. 247, 1) similar to those of the cupule.

2. *Crystal Layer.* An interrupted hypodermal layer of thin-walled, isodiametric cells, each containing a large rhombohedral crystal of calcium oxalate, is clearly seen both in transverse and tangential sections.

3. *Stone Cells* (Fig. 244, *st*). Radially elongated, spindle-shaped cells up to 56 μ long and 10–20 μ broad, with thick, sparingly porous, and indistinctly stratified walls and narrow lumen make up the outer three or four layers. In the inner layers these pass by degrees into isodiametric cells with walls narrower than the lumen.

At the apex of the fruit the dense stone cell tissue is replaced by a brown parenchyma in which are numerous small stone cells with brown walls and contents and broad lumen. Similar cells form a second hard layer further inward. The stone cells of the basal portion of the pericarp have characteristic branching pores.

4. *Outer Mesocarp* (Figs. 244, *mes*). The loosely united cells of this tissue in the ripe fruit are much compressed. The only noticeable

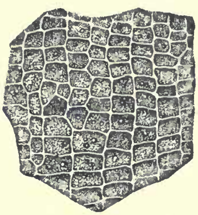


FIG. 245. Acorn. Epicarp in surface view. ×160. (MOELLER.)

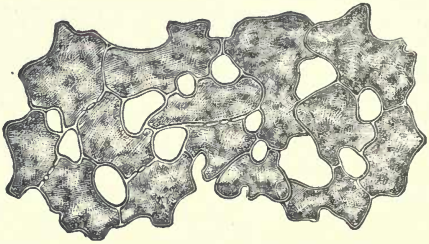


FIG. 246. Acorn. Brown parenchyma of pericarp. ×160. (MOELLER.)

cell-contents are occasional crystal clusters of calcium oxalate. Through this tissue pass the fibro-vascular bundles

5. *Inner Mesocarp.* A spongy parenchyma (Fig. 246) of cells arranged end to end in longitudinal rows forms a characteristic tissue. In cross section these cells are round, in tangential section elongated with numerous connecting arms. The contents are yellow-brown.

6. *The Endocarp* is characterized by the numerous exceedingly thin-walled hairs (Fig. 247, 2), also by the presence of small crystals of various forms.

The Spermoderm is thicker over the furrows of the cotyledons than in other parts.

1. *Outer Epidermis.* The thin-walled, tabular cells are polygonal in surface view, both the walls and the contents being of a deep brown color. Hairs from this layer are shown in Fig. 247, 3.

2. *The Middle Layers*, through which ramify the bundles, consist of a loose brown parenchyma containing crystals of various forms.

3. *The Inner Epidermis* is much the same as the outer.

Embryo (Fig. 248). The polygonal epidermal and subepidermal cells of the cotyledons contain distinct nuclei, each inclosing a crystalloid. Similar nuclei occur along with starch grains in the small subepidermal cells. The remainder of the tissue is a parenchyma with round cells about 100 μ in diameter, having very small intercellular spaces at the angles. They are closely filled with ellipsoidal or irregular elongated starch grains (*st*) usually 15–20 μ, rarely and only in some varieties,

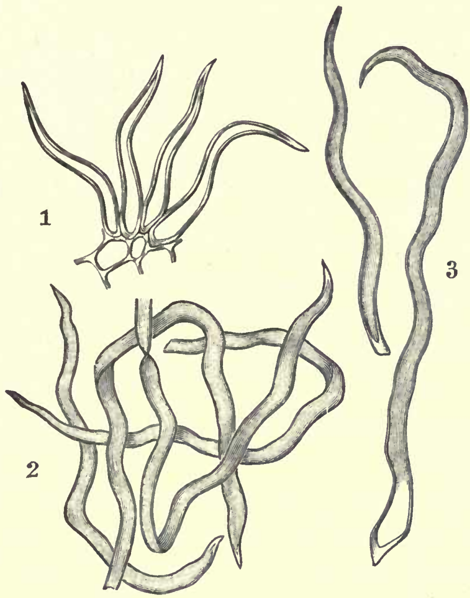


FIG. 247. Acorn. Hairs: 1 from epicarp; 2 from endocarp; 3 from spermoderm. (MOELLER.)

50 μ long with very distinct, elongated hilum. The grains usually occur singly, although twins and various larger aggregates similar to those found in tapioca, sago, and buckwheat are not uncommon. The ellipsoidal forms remind us of the leguminous starches. Fibro-vascular bundles with small spiral vessels pass through the ground tissue.

DIAGNOSIS.

Acorn Coffee is a product of considerable importance. It is prepared from the shelled nut and should contain only traces of the tissues of the pericarp and spermoderm. The conspicuous elements are the ellipsoidal or irregularly elongated starch grains (Fig. 248, *st*) with elongated hilum, reminding us of leguminous starch. These are distorted in the roasted product.

Acorn Flour is mixed with chocolate and other food preparations.

Acorn Shells are used as an adulterant of acorn coffee and possibly of other food products. The quadrilateral epicarp cells (Fig. 245) in regular rows overlying the crystal cells, the spindle-shaped stone cells (Fig. 244, *st*) with narrow lumen, also other forms with broad lumen, and

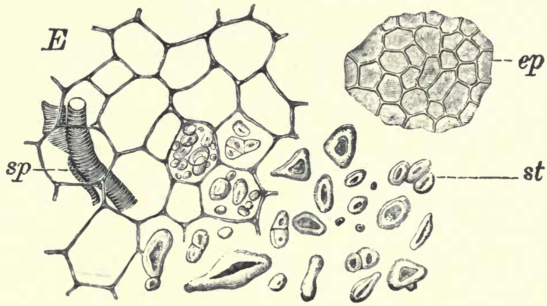


FIG. 248. Acorn. Elements of cotyledon. *ep* epidermis; *E* parenchyma; *st* starch; *sp* spiral vessel. ×300. (MOELLER.)

finally the exceedingly thin-walled hairs (Fig. 247), are the tissues of most importance in diagnosis.

The Cupule is also said to serve as an adulterant. The geniculate hairs of the outer epidermis with constricted base, also the stone cells of the middle layers are the elements of diagnostic value.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Berg (3); Hanausek, T. F. (10, 16); Harz (18); Hassell (19); Macé (26); Moeller (29); Villiers et Collin (42); Vogl (43, 45).

HAGER: Ueber Eichelkakao und Chokolade. Pharm. Ztg. 1888, **33**, 511.

HANAUSEK, T. F.: Mikroskopische Untersuchung eines höllandischen Eichelkakao. Ztschr. Nahr.-Unters. Hyg. 1887, **1**, 247.

MICHAELIS: Eichelkakao, Eichelchokolade. Pharm. Ztg. 1888, **33**, 568.

MITLACHER: Die Fruchthüllen der Eichel (Fructus Quercus sessiliforæ) und ihre mikroskopische Feststellung als Beimengung zum Eichelkaffee. Ztschr. allg. österr. Apoth.-Ver. 1901, **39**, 1.

TARDIEU: Eichelmehl enthaltendes Weizenmehl. Ann. chim. analyt. 1898, **3**, 307.

TSCHIRCH: Untersuchung der Eichel-Kakaosorten des Handels. Pharm. Ztg. 1886, **32**, 190.

BEECH-NUT.

The European beech (*Fagus sylvatica* L.) and the American species (*F. ferruginea* Ait.) yield nuts which, like the walnuts, contain no starch but a high percentage of oil. Beech-nuts are collected on a commercial scale in the forests of Europe for oil production, the cake being utilized as a cattle food. Owing to the presence of cholin the cake is poisonous for horses, but is not injurious to bovine cattle or swine.

The American beech grows in abundance in the eastern half of the United States. In Virginia and other states the nuts are eaten by swine as they drop from the tree, the ham and bacon of these animals being especially prized for their fine flavor; but in most sections they fall a prey to squirrels and other wild animals.

The brown nuts are triangular, winged near the apex, and clothed with a coat of minute hairs hardly visible except under a lens. Two of these nuts are borne in a prickly involucre or cupule, which splits into four valves. The ovary is trilocular, each with two ovules, but the partition wall disappears during development and only one ovule reaches maturity, completely filling the fruit cavity. Remains of the partitions are evident on the inner surface of the pericarp as ridges running through the middle of the three sides. Silky hairs occur in some numbers along these ridges. The brown spermoderm is of thin papery texture and is united with a still thinner endosperm. Running through one of the angles is the raphe, which sends off several distinct branches running through the other two angles as well as in the tissues between. At first sight the embryo appears homogeneous, but on closer inspection is seen to consist of much folded cotyledons connected with a minute radicle.

HISTOLOGY.

Either the European or American beech-nut may be used for study, as both are essentially the same in structure.

Pericarp. Transverse sections are cut from the middle of the sides and at the angles, also tangential sections at different depths.

1. *The Epicarp Cells* are polygonal with moderately thin, faintly beaded walls and contain either a brown homogeneous material or well-formed crystals. The hairs of this layer are short, pointed, and usually thick-walled. Hanausek notes that thin-walled, twisted hairs, also multicellular forms are occasionally found.

2. *Sclerenchyma.* Stone cells in 5–10 layers form a dense hypodermal tissue about the nut. These are rounded, nearly isodiametric, and have thick and distinctly porous walls and brown or yellow-brown contents.

3. *The Mesocarp* consists of several layers of tangentially elongated parenchyma cells with thick, porous walls, impregnated with brown coloring matter. As appears in cross section, large V-shaped bundles of bast fibers pass through the brown parenchyma in the angles, strengthening the tissues. In the inner portion of the layer broad fibrovascular bundles with strongly developed bast fibers form an almost continuous layer. Accompanying the bundles are crystal fibers.

4. *The Endocarp* is of parenchyma cells interspersed about the partition wall with long, thin-walled hairs.

Spermoderm. 1. *Epidermis.* The cells are polygonal, often over 50 μ in diameter and have deep brown walls, which Pfister notes are suberized.

2. *Brown Parenchyma Cells* similar to those of the epidermis but smaller, form one or two subepidermal layers.

3. *A Spongy Parenchyma* of colorless compressed cells, and

4. *An Inner Epidermis* of thin-walled elements completes the speromderm.

Endosperm. Adhering to the inner surface of the spermoderm is a single layer of thick-walled, polygonal aleurone cells forming the endosperm.

Embryo. The epidermis on the inner sides of the cotyledons has larger cells than on the outer. Both layers have thickened outer walls. The ground tissue in the outer portion of the cotyledon consists of isodiametric cells passing into one or more layers of palisade cells in the inner portion. Procambium bundles occur in the middle layers. The cell-contents are aleurone grains up to 15 μ, fat, and calcium oxalate rosettes. Hanausek notes that a single rosette is present in each cell as may be seen after treatment with alkali.

DIAGNOSIS.

Undecorticated Beech-nut Cake can be easily identified by the tissues of the pericarp and spermoderm, provided fragments sufficiently large for cutting sections are present; otherwise the task is not an easy one as the tissues, although both striking and varied, are not especially characteristic in surface view. The epicarp with short, usually thick-walled hairs, the isodiametric stone cells, the bundles accompanied by bast fibers and crystal fibers, and the long, thin-walled hairs of the endocarp, are the most striking elements.

Decorticated Beech-nut Cake is still more difficult of diagnosis. The tissues of the cotyledons are much the same as those of numerous other oil seeds, and the brown cells of the spermoderm in surface view are not distinctive. Tissues of the pericarp, particularly the hairs, are however present even in decorticated cake, and on these the microscopist must largely depend in forming his conclusion.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Böhmer (23); Collin et Perrot (9); Hanausek, T. F. (17, 48); Harz (18).

PFISTER: Buchnusskuchen. Landw. Vers.-Stat. 1894, **43**, 445.

HAZELNUT.

The hazelnut is of no little importance in Europe both as a table nut and for the production of hazel oil ("nut oil"), which is used on the table and in the arts.

The numerous European and Asiatic varieties have probably been derived from three species: the common hazel (*Corylus Avellana* L.), Lambert's hazel or filbert (*C. tubulosa* L.), and the Turkish hazel (*C. colurna* L.), of which the Spanish or cobnut (*C. pontica* Koch) is perhaps but a variety. Three native American species (*C. Americana* Walt., *C. rostrata* Ait., and *C. Californica* Rosc.) also yield nuts of excellent quality, but are not as yet cultivated.

The nuts of all the species named are inclosed in a leafy involucre consisting of two more or less foliaceous members, which in *C. tubulosa*, *C. rostrata*, and *C. Californica* is prolonged into a narrow tube, but in the other species is short and open. The nuts of the various species and varieties differ both in size and in the ratio of breadth to length. They have a broad circular scar at the base, and a short blunt point. On the lower portion they are smooth, on the upper covered with a gray bloom consisting of numerous minute hairs visible only under a lens. The pericarp or shell consists of a hard outer coat 1–2 mm. thick and a brown spongy inner coat. Through the outer part of the hard coat, corresponding to longitudinal streaks visible from without, pass fibro-vascular bundles which in cross section appear as dark-brown spots in the light-colored, woody ground tissue. One, rarely two, hemitropous nuts are suspended from the top of the cavity. Each seed consists largely of fleshy cotyledons, the radicle, the brown spermoderm and the colorless endosperm forming but a small portion of its bulk. The short raphe, about half the length of the nut, and the nerves radiating from the chalaza are distinctly seen through the spermoderm.

HISTOLOGY.

Commercial hazelnuts of any variety may be studied. After noting the macroscopic characters, particularly the bloom on the outer surface, the brown fibro-vascular bundles of the pericarp and the spermoderm with its raphe and nerves, transverse sections and surface mounts should be prepared.

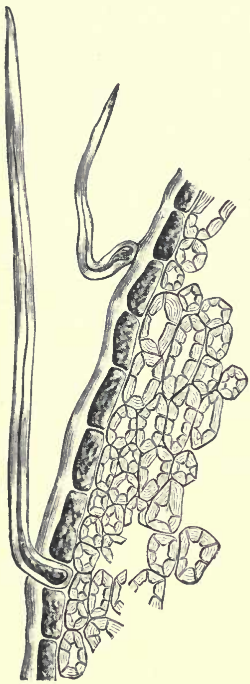


FIG. 249. Hazelnut (*Corylus sp.*). Epicarp with hairs, and stone cells in cross section. (MALFATTI.)

Pericarp. 1. *The Epicarp* is best obtained by boiling the shell in dilute alkali and scraping with a scalpel. Fragments from the upper part of the shell consist of thin-walled, isodiametric, polygonal cells interspersed with numerous hairs. In cross section (Fig. 249) it may be seen that the hairs are deeply planted between the thin-walled cells. Characteristic of these hairs are their thick walls, the lumen being scarcely evident except in the basal portion, and the bright yellow color produced by alkali. On the lower half of the shell the layer consists of isodiametric, somewhat elongated cells and hair scars, the hairs themselves usually being lacking.

2. *Outer Stone Cells* (Fig. 249). The hard portion of the shell is in three layers, each of colorless stone cells distinctly different from those in the others. The stone cells in the outer layer are characterized by their rounded isodiametric form, distinct outline, and especially, as noted by Malfatti, by their loose arrangement. They gradually increase in size from 15 μ in the outer layers to 50 μ in the inner. Being in loose contact, they separate readily on grinding. Through this layer pass the large bundles, often 500 μ in diameter, which in the ripe nut are usually disorganized.

3. *Middle Stone Cells.* In this layer the stone cells are radially elongated and closely arranged.

4. *The Inner Stone Cells* are larger than those in the two outer layers and have thicker walls and broader cavities. They are either isodiametric or tangentially elongated and have brown contents. Hanausek has rightly observed that their contour is ill-defined on direct examination, but becomes more distinct on addition of alkali. This latter reagent imparts to the walls of the stone cells in all three layers a bright yellow color.

5. *Brown Parenchyma*, at maturity more or less disorganized, forms the inner layers.

Spermoderm. 1. *The Outer Epidermis* of polygonal cells with distinct outline and colorless contents is clearly seen in surface mounts or cross section.

2. *Hypoderm.* Two or three cell layers similar to the epidermis form the next coat.

3. *Brown Cells* make up the compressed inner tissues.

Endosperm. One to three layers of typical aleurone cells are closely united with the embryo.

Embryo. Hanausek first observed that the cells of the embryo contain spherical aleurone grains 16–30 μ in diameter, with rounded globoids embedded in a yellowish granular ground substance.

These are clearly seen on mounting in alcohol sections previously extracted with ether. In water the ground substance gradually disintegrates, liberating the globoids. Hanausek states that minute granules of starch are also liberated, but these are not commonly evident.

DIAGNOSIS.

Hazelnut Meal prepared from the kernel without removal of the fat has been used in conjunction with wheat and rye flour for bread-making.[1] This product consists chiefly of embryo tissues with the characteristic yellow, globular aleurone grains from which the rounded globoids gradually separate on the addition of water. Fragments of the spermoderm are also present.

Hazelnut Cake. Meager details are available as to this product, although considerable quantities must be obtained in the manufacture of hazelnut oil. Its microscopic characters are the same as of the unextracted kernel.

Ground Hazelnut Shells have been detected by Malfatti, Micko, T. F.

[1] Plagge and Lebbin: Veröffentlichungen auf dem Gebiete des Militär-Sanitätswesens 1897, **12**, 193.

Hanausek, Mansfeld, and others as an adulterant of cinnamon. The elements (Fig. 249) are the epicarp cells interspersed with hairs or hair scars, the colorless stone cells of the woody portion of the pericarp, and the brown obliterated tissues of the inner pericarp. The hairs are characterized by their thick walls, narrow lumen and the yellow color produced on addition of alkali. Among the stone cells are isodiametric forms of various sizes from the outer layers, readily separating from one another on grinding, elongated forms from the middle layers, and large cells with thick walls and broad lumen from the inner layers.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Hanausek, T. F. (16); Villiers et Collin (42); Vogl (45).

HANAUSEK, T. F.: Ueber den hystologischen Bau der Haselnusschalen. Ztschr. allg. österr. Apoth.-Ver. 1892, **30**, 61.

HANAUSEK, T. F.: Ueber einige, gegenwärtig im Wiener Handel vorkommende Gewürzfälschungen. Ztschr. Nahr.-Unters. Hyg. 1894, **8**, 95.

MALFATTI: Eine neue Verfälschung des Zimmtpulvers. Ztschr. Nahr.-Unters. Hyg. 1891, **5**, 133.

MICKO: Haselnusschalen als Verfälschungsmittel der Gewürze. Ztschr. allg. österr. Apoth.-Ver. 1892, **30**, 42.

MISCELLANEOUS NUTS.

BRAZIL-NUT.

The Brazil-nut, also known as the Para-nut from the port of shipment, and incorrectly as the castanea-nut, is the seed of a large tree (*Bertholletia excelsa* Humb. et Bpl. order *Myrtaceæ*) growing in forests on the banks of the Amazon and Rio Negro Rivers. Another species, *B. nobilis* Miers., also yields a similar nut.

The fruit is spherical, about the size of a cocoanut, which it further resembles in having a hard endocarp. The ovary is four-celled, each containing numerous ovules borne on a central placenta in two rows; but on ripening the partitions disappear. At maturity the seeds are usually three-sided, resembling the segments of a small orange. On the surface they are transversely roughened and of a dark gray color. The hard shell-like spermoderm, as seen in section, has an outer coat 1 mm. or less thick of a light color, and an inner coat, of softer dark-brown tissue with a glossy inner surface. Running through the inner coat in the angles is a hard tissue, triangular in cross section, with broad bands of vascular elements on the inner side through which the tissues readily separate. On carefully cutting away the inner tissues, it may be seen that the vascular elements forming the band in the straight edge belong to the raphe, the delicate lateral ramifications being directed upward or transversely, while those in the two curved edges proceed from the chalaza with lateral ramifications directed downward. The homogeneous flesh of the nut consists entirely of radicle.

HISTOLOGY.

Spermoderm. Transverse sections should be cut through the shell at the angles and through the tissues half way between the angles. Radial longitudinal sections at the angles and tangential sections through the epidermis and the band-like tissues of the raphe and its branches are also instructive.

1. *Palisade Cells.* The epidermis consists of greatly elongated, sclerenchyma cells arranged perpendicularly to the surface, forming a palisade layer 0.5–1 mm. thick. These remarkable cells have narrow branching cavities and thick colorless walls, except at the extreme outer end, where the cavity is broad. In tangential section they are polygonal, varying up to 50 μ in diameter.

2. *Outer Brown Tissue.* This is a spongy parenchyma with small cells containing a deep brown substance responding to the tests for tannin. On the sides of the seeds it passes directly into the inner brown tissue.

3. *Stone Cells.* At the angles these cells form a hard tissue, broadly triangular in cross section, extending the entire length of the seed. The cells are for the most part isodiametric, reaching a maximum diameter of 100 μ. The transition to brown tissue in the outer layers is gradual, the intermediate tissues being composed of stone cells interspersed with parenchyma elements. The stone cells have colorless walls of medium thickness and brown contents, and are conspicuous both in sections and in the powdered shells. In the inner layers the cells are longitudinally elongated.

4. *Fibro-vascular Bundles.* The thin broad bands on the inner surface of the stone-cell tissue forming in the straight edge the raphe, and in the curved edges the branches of the raphe, contain numerous small spiral vessels. As the inner spermoderm separates from the outer through this tissue, tangential sections are easily prepared.

5. *Inner Brown Tissue.* The cells in the inner layers are larger than those of the outer layers and form a closer tissue.

Endosperm. After removing the shell, the meat of the nut, consisting entirely of radicle, is in perfect condition for sectioning either with a razor or a microtome. In cross sections we note that the cells in the first two or three layers are sharply differentiated from those further inward, suggesting that they may not belong to the embryo at all, but are endosperm or less probably perisperm.

Embryo. Next follow 8–15 layers of thin-walled, circular cells 30–60 μ in diameter in loose contact. A layer of narrow longitudinally-elongated cells forms a distinct ring separating the outer from the inner layers. A uniform tissue of round cells varying up to 100 μ in diameter makes up the inner portion of the meat. All the cells of the embryo contain aleurone grains, of which the solitary grains, often 30 μ in diameter, each with a large crystalloid and an irregular globoid mass, are especially noticeable. Because of these grains which are among the most striking proteid bodies found in the vegetable kingdom, the nut is often used in laboratories as a material for study.

DIAGNOSIS.

The Meat or *Embryo* is used whole or broken in confectionery. In sections mounted in turpentine the large aleurone grains are the noticeable elements. Fragments of the brown inner spermoderm are often attached to the outer surface.

The Cake remaining after expressing the oil contains the elements already noted.

Shells of the Brazil-nut have been ground for adulterating spices. This material is identified by the following characters: (1) the colorless, sclerenchyma palisade cells of the spermoderm which occur in groups of more or less rectangular form; (2) the deep-brown parenchyma; (3) the isodiametric stone cells with colorless walls and often with deep-brown contents.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Hanausek, T. F. (16); Tschirch (39).
Hofmeister: Pflanzenzelle. 1867, 178.
Millardet: Ann. Sc. nat. iv sér. 34.

PISTACHIO-NUT.

The pistachio tree (*Pistacia vera* L. order *Anacardiaceæ*), was cultivated in Asia Minor and Egypt in the days of Joseph, and was introduced from these countries into Greece and Rome at an early period. Its culture is still limited largely to the Mediterranean region.

The fruit is a dry drupe with an oily seed, which, freed from the pericarp, is known in commerce as the pistachio-nut or green almond, and is extensively used in pastries and confectionery. The seed is elongated, 10–25 mm. long, with a pronounced ridge on the dorsal side and a shallow depression on the ventral side near the base. The lower portion is flattened from front to back, while the upper portion is flattened in a plane at right angles to the last. After soaking or boiling in water, the spermoderm and endosperm may be separated as a thin skin from the embryo. On the dorsal side, where it is also thickest, the spermoderm is dark purple, on the ventral side, green. Closely attached to the spermoderm is the colorless, silky-lustrous endosperm. The embryo consists of large cotyledons of a green color attached to a radicle situated directly beneath the dorsal ridge.

HISTOLOGY.

The Spermoderm, together with the endosperm, is sectioned without separation from the embryo.

1. *Outer Epidermis.* The cells are polygonal, 30–60 μ in diameter, and have faintly beaded walls.

2. *The Middle Spermoderm* consists of thin-walled cells and fibro-vascular bundles. On the ventral side only a few cell layers are present, but on the dorsal side, eight or more layers. The cells on the dorsal side, not only of the middle layers but also of the epidermis, contain a water-soluble substance of a carmine or brown color which becomes green with alkali, but is not altered by chloral.

3. *The Inner Epidermis* on the dorsal side is also of thin-walled, inconspicuous elements, but on other parts is an exceedingly characteristic tissue of small, distinctly porous cells. As seen in surface view, the cells are 7–15 μ in diameter, sharply polygonal, with beaded walls. Cross sections show that some of the cells are divided by tangential partitions. This layer is here tentatively classed with the spermoderm, although further investigation may show it to be perisperm.

Endosperm. The outer endosperm consists of a variable number of layers of typical aleurone cells, the inner layers of more or less obliterated cells forming a hyaline membrane.

Embryo. The green color of the tissues is more apparent to the naked eye than under the microscope. The thin-walled cells contain spherical aleurone grains, most of which are small (3–5 μ), some however larger (8–14 μ).

DIAGNOSIS.

Pistachio-nuts, whether whole or chopped, are recognized (1) by the carmine or brown coloring matter in the spermoderm becoming green with alkali, and (2) by the exceedingly small but distinctly porous cells of the inner epidermis.

Almonds and other nuts dyed with coal-tar colors are sometimes substituted for genuine pistachio-nuts. In a suspected sample, foreign tissues should be searched for under the microscope, and tests made for foreign dyes.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Hanausek, T. F. (16); Planchon et Collin (34); Vogl (43).

PINE-NUT.

The seed kernels or "nuts" of several species of pine, notably the stone pine of Italy (*Pinus Pinea* L. order *Abietineæ*), and the Cembra or Swiss pine (*P. Cembra* L.), including the Siberian variety (var. *Siberica*), are highly prized for their delicate resinous flavor.

As found on the market, the kernels, consisting of the endosperm and embryo entirely free of spermoderm, are narrow, elongated, 1–1.5 cm. long, smooth, and of an ivory-white color. After boiling with water, the elongated embryo embedded in the axis of the endosperm, may be easily separated. It consists of twelve needle-shaped cotyledons 5–7 mm. long and a radicle of about the same length.

HISTOLOGY.

In microscopic structure both the endosperm and the embryo entirely lack characteristic elements. The thin-walled, for the most part isodiametric cells contain fat and rounded aleurone grains usually 3–5 μ, less often 10–12 μ, in diameter.

PART VI.

FRUIT AND FRUIT PRODUCTS.

FRUIT.

Fruit, in the common acceptance of the term, includes such succulent fruits as are suited for table use. Dry fruits (cereals, buckwheats, pepper, anise, cocoanut, etc.), some known as seeds, others as nuts, are described elsewhere in this work.

Only those fruits used for the preparation of preserves, jams, and other commercial products are here considered.

Fruit Products.

The products of pomes, drupes, berries and other succulent fruits include dried and candied fruits, jams, marmalades, preserves, jellies, sauces, and catsups. Of these some contain all the histological elements of the fruits, including the seed tissues, others only the elements of the fruit flesh, and others still no cellular matter whatever, or only traces.

Dried Fruits are prepared from the whole fruit in the case of figs, dates, raisins, Xanti currants, prunes, and various berries; from the fruits freed from stones in the case of peaches, apricots and cherries; and from the pared and cored fruits, in the case of apples and pears. Substitution of cheaper fruits is not often practiced, as the macroscopic characters and taste of most of the products cannot be successfully imitated. The most objectionable practice is the bleaching with sulphur or "sulphuring" of peaches, apples, apricots, pears, and similar fruits that show a tendency to turn brown on drying.

Jams, Marmalades, and Other Preserves, like dried fruits, are prepared either from the whole fruit or the fruit flesh. After addition of sugar the mixture is boiled down to the proper consistency.

The common adulterants may be classified as follows:

1. *Foreign Pulp and Gelatinous Material.* Under this head may be included the pulp of turnips, beets, apples and figs; the residues or pomace obtained in the manufacture of fruit juices and jellies; also starch-paste, gelatin, agar-agar, and other vegetable materials used to give "body" to fraudulent mixture.

It is stated on creditable authority that artificial raspberry jam has been made in America in which grass seed took the place of fruit seeds. Another fraud, more difficult of detection, consists in mixing the residues from the manufacture of fruit juices or jellies with water, gelatinous materials, dyes and flavoring substances.

2. *Sweeteners* other than cane-sugar include glucose sirup and also chemical sweeteners, such as saccharine, dulcin, etc.

3. *Dyes.* Cochineal, cudbear, and various vegetable dyes, formerly employed in food products, are now largely replaced by dyes of coal-tar origin.

4. *Artificial Flavors.* These are mixtures of ethers, such as ethyl acetate, ethyl butyrate, amyl butyrate, etc., prepared in imitation of the real fruit flavors. Banana and pineapple flavors are quite closely imitated, but the imitations of strawberry and raspberry flavors are sickening mixtures, with little resemblance to the genuine.

5. *Vegetable Acids.* Citric and tartaric acids are employed to give artificial fruit products the requisite acidity, also to bring out the flavor of certain mild-flavored fruits.

6. *Chemical Preservatives.* Formerly salicylic acid was the common preservative of fruit products, but recently, at least in America, sodium benzoate has largely taken its place. Saccharine may also be classed under this head, as it is not only a sweetener but also a preservative.

Fruit Juices and Jellies, being strained products, are usually quite free from seeds, skins and pulp cells, although small fragments of tissues may sometimes be found on careful search.

The adulterants are the same as are used in preserves, excepting the pulp of fruits and vegetables.

Tomato Catsup, a popular sauce in America, consists of tomato pulp freed from seeds, mixed with spices and vinegar. It is adulterated with foreign pulp, notably that of the pumpkin, coal-tar and other dyes, and chemical preservatives.

Chili Sauce is made from tomatoes, peppers, spices and vinegar. It is not usually strained, and therefore contains seeds of both the tomatoes and the peppers. The adulterants are the same as of tomato catsup.

Methods of Examination.

Preliminary Examination. Seeds, styles, fragments of skin, and other tissues are picked out either from the original material, the residue after washing on a sieve, or the deposit that settles after dilution and shaking. These may often be identified by the macroscopic characters, but in doubtful cases should be examined under the microscope.

Artificial flavors imitating strawberry, raspberry, and some other fruit flavors, are recognized by their characteristic odor and taste, which are quite different from those of the real fruits. Apple jelly also has a more or less characteristic odor, which is especially marked on heating the

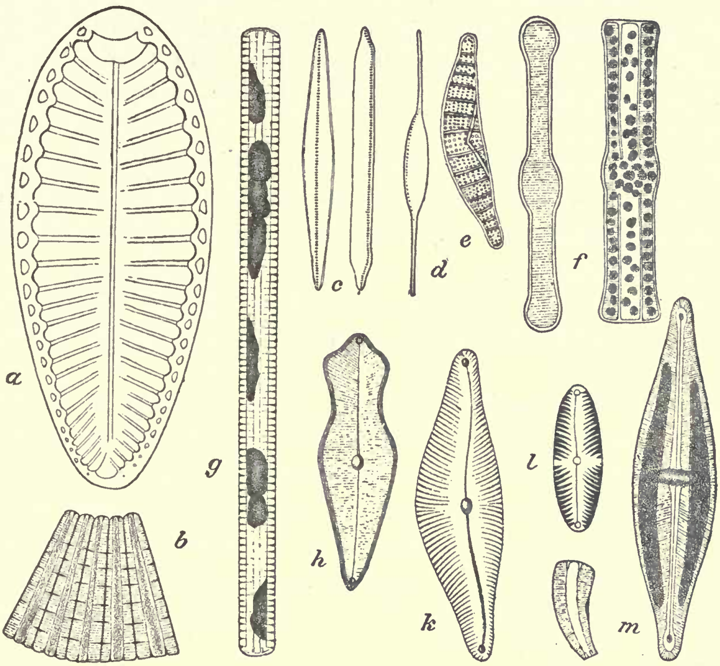


FIG. 250. Common Diatoms. *a Surirella splendida; b Meridion circulare; c Nitzschia linearis; d Nitzschia acicularis; e Epithemia Zebra; f Tabellaria fenestrata; g Synedra Ulna; h Gomphonema acuminatum; i Rhoicosphenia curvata; k Cocconema Cistula; l Navicula Stauroptera; m Stauroneis Phoenicentron.* (MEZ.)

product. Sulphites or glucose containing sulphites, if used in considerable amount, impart a disagreeable sulphurous taste.

Chemical Examination. Methods for the detection of starch-paste, gelatin, glucose, dyes, preservatives, etc., are described in the works on the chemical analysis of foods named on page 5.

Microscopic Examination. Direct examination is made both of the original material and of the seeds, styles, skin, fibro-vascular bundles, etc., separated by washing on a sieve or by allowing the diluted material to settle. Jams and similar saccharine products can be mounted without dilution, the gelatinous portion of the material forming a suitable medium in which to examine the solid fragments. Owing to the heating with sugar sirup in the process of manufacture, as well as to the absence of starch grains, fat and similar interfering substances, the tissues are beautifully distinct and treatment with clearing reagents is usually quite unnecessary. Seeds may be broken up on the slide, or may be held in a hand-vice or between pieces of soft wood and sectioned with a razor.

Agar-agar. Marpmann boils the jelly with 5 per cent sulphuric acid, adds a few crystals of potassium permanganate and allows to settle. If microscopic examination of the sediment discloses diatoms, agar-agar is probably present.

Schimper heats the jelly on a piece of platinum foil and examines the residue in a drop of dilute hydrochloric acid for diatoms (Fig. 250). If, however, only small amounts of agar-agar are present he recommends Marpmann's method.

Lagerheim calls attention to the presence of characteristic fibrous bodies, pointed at one end, which are always present in agar-agar and are readily identified.

Lagerheim's Test for Benzoic Acid. Place a portion of the material on a watch-glass and cover with a glass plate; heat to boiling, allowing the steam to condense on the plate. Remove the latter while still hot, allow the drops of liquid to evaporate and examine the residue under the microscope. If benzoic acid is present, branching crystalline deposits, resembling frost on the window-pane, are evident. As stated by Lagerheim, this test is so delicate as to permit the detection of the small amounts of benzoic acid naturally present in cranberries.

BIBLIOGRAPHY.

LAGERHEIM: Om den mikroskopiska undersokningen af marmelad. Svensk Farm. Tidsk. 1901, 5.

LAGERHEIM: Kralitativ bestänining af benzoesyra och salicylsyra i närings-och njutningsmedel genom direkt sublimering. Svensk Farm. Tidsk. 1903, 7.

MARPMANN: Beiträge zur mikroskopischen Untersuchung der Fruchtmarmeladen. Ztschr. angew. Mikros. 1896, 2, 97.

MÉNIER: Falsification de la gelée de groseille du commerce découverte par les Diatomées. Nantes. 1879.

SCHIMPER: Anleitung zur mikrosk. Unters. der veg. Nahr.-u. Genussm. Jena, 1900, 146.

WINTON: Beiträge zur Anatomie des Beerenobsten. Ztschr. Unters. Nahr.- u. Genussm. 1902, 5, 785. Conn. Agr. Exp. Sta. Rep. 1902, 288.

ROSACEOUS FRUITS (*Rosaceæ*).

Most of the important tree fruits and several of the bush fruits belong to this family. They are grouped under three subfamilies, each with quite distinct characters.

1. **Pomes** (Apple, Pear, Quince). The five carpels are united into a fleshy fruit, bearing the remains of the calyx teeth in a depression at the end. The morphology of pomes has long been a subject for dispute, some botanists asserting that the outer fruit flesh is calyx tube, others that it is receptacle. At present the preponderance of evidence favors the latter theory.

The epicarp of the quince is hairy, and the mesocarp of the pear and quince contains groups of stone cells. In all the drupes the cartilaginous endocarp of each of the five locules is made up of sclerenchyma cells. The seed is quite complicated in structure, consisting of a spermoderm of 5–6 more or less characteristic layers, a thin perisperm, an endosperm of a few layers of aleurone cells, and a bulky embryo.

2. **Drupes** (Almond, Peach, Apricot, Plum, Cherry). The most striking characteristic is the thick, hard endocarp or stone. Only one of the two ovules usually matures. The spermoderm usually consists of four layers, of which the epidermis is characterized by groups of thin-walled stone cells. The perisperm, endosperm and embryo are similar to those of pomes.

3. **Other Rosaceous Fruits.** The raspberry and blackberry are multiple drupes, the small individual fruits agreeing in general structure with the true drupes. The succulent part of the strawberry is a receptacle, on which are diminutive achenes.

APPLE.

The apple is not only the leading table and culinary fruit of the temperate zone, but in addition ranks next to the grape for the production of fermented liquors.

It is a native of eastern Europe and southwestern Asia, and has been cultivated since prehistoric times in the Old World, and since colonial times in America and Australia. The common species (*Pyrus Malus* L.) includes many varieties, differing greatly in size, shape, color of skin and flesh, texture, flavor, acidity, and keeping qualities.

Notwithstanding the variations in shape, all apples have a depression at one end, in which are borne the withered calyx teeth, and another more pronounced at the other end, in which is inserted the woody stem. The skin is tough and closely adherent to the fruit flesh. In the receptacle or outer fruit flesh are embedded the five wedge-shaped carpels, which are also fleshy, except for the cartilaginous endocarp lining the cavities. At full maturity an axial cavity appears in the fruit and the endocarps split on their inner edges, thus opening communication between the cell cavities and the axial cavity. Each cell contains two brown, flattened obovoid seeds.

The crab-apple (*P. baccata* L.) is the only other species cultivated to any considerable extent for fruit. In this species the fruit is small, seldom exceeding 40 mm. in diameter, and is useful only for cooking. The calyx teeth drop before the fruit reaches maturity.

HISTOLOGY.[1]

Fresh ripe apples, either hardened in alcohol or without special treatment, supply material for preparing sections of both the fruit itself and the seeds.

Receptacle and Pericarp. 1. *Epidermis.* The cells of the epidermis have a cuticle 12–15 μ thick. In surface view, the thick-walled mother cells, divided by much thinner walls into 2–5 more or less quadrilateral daughter cells, remind us of windows, hence the name "window cells." The daughter cells range from 15—50 μ in diameter, being about twice as large as in the pear. In the calyx and stem depression, the walls throughout are of more uniform thickness. Here also, particularly in the calyx depression, are found long, thin-walled, strap-shaped, pointed hairs. The contents of the cells are brown granular masses, occasional chlorophyl grains and, in the case of colored apples, reddish or violet coloring matter in solution, which becomes greenish with iron salts, and blue-green with alkalies changing back to its original color with acids.

2. *Hypoderm.* Two to three layers of rather small, more or less porous cells underlie the epidermis. As appears in cross section, they are tangentially elongated, and the walls are collenchymatously thickened. Starch grains 5–14 μ long and 4–10 μ broad, the larger grains with elongated hilum, the smaller often in twins, triplets, or larger aggregates, are sometimes found in the larger cells. In highly colored apples, the cells contain coloring material in solution.

3. *Fruit Flesh.* A loose parenchyma of large, thin-walled cells with indistinct contents makes up the bulk of the fruit flesh. When the fruit

[1] Based on the investigations of Malfatti, supplemented by observations of the writer.

is fully ripe these cells are easily separated from one another by pressing with a cover-glass, appearing like rounded, somewhat elongated, collapsed sacs.

On cutting an apple transversely into halves, we note an indistinct line of demarcation between the fruit flesh of the receptacle and that of the five united carpels. The structure of the fruit flesh is much the same in both receptacle and mesocarp. In the two or three layers adjoining the endocarp, the cells are small, elongated in various tangential directions, and contain occasional oxalate crystals.

4. *Endocarp.* The parchment-like endocarp consists of 3–4 layers of thick-walled, sclerenchyma fibers, and elongated cells, extended in various directions parallel to the inner surface, forming a tissue similar to that found in the endocarp of coffee. Rows of thin-walled crystal-cells are distributed among the fibres. Pores are distinct in the outer layers, indistinct in the inner. In the cleft formed by the splitting of the ripe carpels at the sutures, parenchyma cells, and curious, jointed, branching warty hairs (Fig. 251) often make their appearance. Some

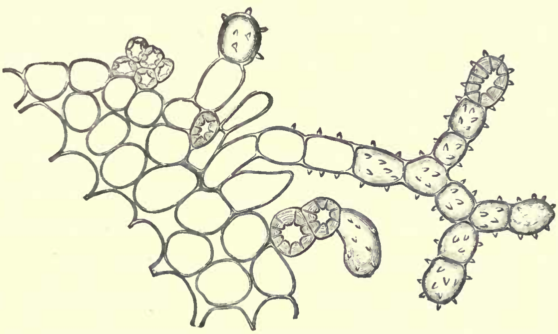


FIG. 251. Apple (*Pyrus Malus*). Hairs from suture of endocarp. (MALFATTI.)

of the individual cells of the hairs, particularly the terminal ones, are sclerenchymatized, thus furnishing a distinction from the similar hairs of the pear. These outgrowths are highly characteristic, but, unfortunately, are not always present.

Spermoderm. Sections should be examined directly in glycerine, and in water, also, for the study of the inner spermoderm, after treatment with Javelle water and staining. Surface preparations mounted in chlor-zinc iodine are instructive.

1. *The Outer Epidermis* is first studied in cross sections mounted in glycerine. The radial and especially the outer walls are greatly thickened

and show a laminated structure. What appear like minute warts on the inner surface of the outer walls are but the sections of the ribs forming the reticulations seen in surface view. The inner lamellæ are mucilaginous and swell greatly on addition of water. Surface sections show that the cells are thick-walled, longitudinally elongated, and conspicuously marked by coarse spiral reticulations.

2. *Hypodermal Fibers* longitudinally arranged, with greatly thickened brown walls, form 6–10 layers, or about half the thickness of the spermoderm. In the débris obtained by scraping, they are distinguished by their slender, tapering form and thick, brown walls.

3. *Tube Cells.* Adjoining the last is a loose tissue of 2–3 layers of longitudinally elongated, rather thin-walled, blunt cells in interrupted contact, resembling the tube-cells of cereals. The cells are further distinguished from the hypodermal fibers by their greater breadth. Diagonal markings are evident after bleaching and staining. In parts the tissue is a typical spongy parenchyma. A brown substance with the reactions of tannin impregnates the walls and partially fills the cells.

4. *Cross Cells.* The next layer resembles the preceding, but the transversely elongated elements are narrower, and in closer contact.

5. *Starch Cells.* A single cell layer of colorless, exceedingly thin-walled cross cells contains minute starch grains. Were it not for these grains the layer would hardly be noticeable.

6. *Inner Epidermis.* These cells are also transversely elongated, but only moderately so, and are further distinguished from those of the preceding layers by their polygonal form and the absence of intercellular spaces. They are impregnated with a brown substance.

Perisperm. On cutting open a seed, a colorless skin may be found between the thick brown spermoderm and the embryo. This consists of perisperm and endosperm.

A hyaline membrane, in section 3–6 μ thick, apparently structureless, separates the spermoderm from the endosperm. It is stained a deep yellow with chlorzinc iodine, whereas the adjoining tissues are stained blue. After this treatment a delicate, cellular network is distinguishable in surface view. The remainder of the perisperm is a colorless, obliterated tissue, with only slight indications of cellular structure.

Endosperm. 1. *Aleurone Cells* form the outer layers. These are colorless, rather thick-walled, in surface view polygonal, and contain aleurone-grains and fat.

2. *Obliterated Cells* complete the endosperm.

The Embryo consists of two oval cotyledons and a relatively small radicle. The cells are thin-walled; the contents consist of aleurone grains and fat.

Stem. Cork cells in 4–6 cell layers form the outer zone, then 4–5 layers of small-celled collenchyma, passing by degrees into the middle bark. The bundles of very delicate cells are partly inclosed on the outer sides by the bast-fiber bundles. On the inner side they adjoin a zone of stone cells, interrupted only by the medullary rays.

DIAGNOSIS.

Preserves. Various products of the apple, such as preserves, jams, jellies, and sauces are articles of commerce. Apple jelly and apple preserves also serve as adulterants of more expensive fruits, the deception being completed by the addition of dyes, artificial fruit ethers, and even grass seed. Apples also enter into the composition of "mince-meat," which in America is sold both moist and desiccated for making pies.

These products either contain only the fruit flesh of the apple, the tissues of which lack distinctive character, with traces of the characteristic elements of the epidermis, the endocarp and the seed, or else, in the case of jellies, no cellular structure whatever. While this lack of characteristic elements renders the microscopic identification of the material as an apple product usually impossible, it facilitates the detection of materials with distinctive characters.

Apple Pomace, the residue from the cider-press, is used for feeding cattle and for other purposes. It contains all the histological elements of the fruit.

The tissues of chief use in diagnosis are the epidermis, the "window" cells of which are larger than those of the pear; the endocarp with thicker-walled fibers than in other pomes; the branching, multicellular, warty hairs from the suture, which, except for the sclerenchyma elements, are much the same as the corresponding hairs of the pear; the longitudinally elongated, reticulated, thick-walled epidermal cells of the spermoderm, which differ markedly from the isodiametric cells of the pear and quince; and finally the tissues of the stem. Products of the ripe apple contain only faint traces of starch

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Hassall (19).

BORDZILOWSKI: Ueber die Entwicklung der beerenartigen und fleischigen Früchte. Arb. Kiewer Naturf. Ges. 1888, **9**, 65.

HOWARD: Microscopical Examinations of Fruits and Fruit Products, U. S Dept. Agr. Bur. Chem. Bull. **66**, 103.

MALFATTI: Beiträge zur Anatomie der Birn- und Apfelfrucht. Ztschr. Nahr.-Unters. Hyg. 1896, **10**, 265.

STRASBURGER: Das botanische Practicum.

STRASBURGER: Das kleine botanische Practicum.

PEAR.

Most of the varieties of pear, including all those cultivated in Europe and America before the early part of the nineteenth century, are forms of *Pyrus communis* L., a native of Europe and western Asia, although a number of the varieties now cultivated in America, including the Le Conte and the Kieffer, are hybrids with the oriental pear, *P. Sinensis* Lindl.

The pear differs from the apple in form, having a more or less tapering stem-end without a depression, also in the texture and flavor of the fruit flesh; but in general morphological details the fruits are identical.

HISTOLOGY.[1]

Receptacle and Pericarp. 1. *The Epidermis* (Fig. 252) consists of "window cells" like those of the apple, but only half as large (10–25 μ). They are covered with a thick cuticle, which however is ruptured in places, particularly about the stomata, with the formation of cork cells beneath. In varieties with a rough skin, the epidermal cells proper give place almost entirely to cork tissues. In the calyx depression are thick-walled, pointed hairs 200–250 μ long.

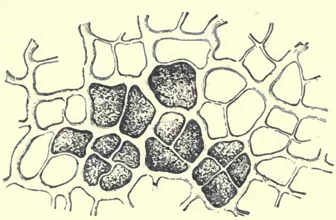


FIG. 252. Pear (*Pyrus communis*). Epicarp in surface view. ×160. (MOELLER.)

2. *A Hypoderm* of 3–4 layers consists of small tabular cells with moderately thickened walls.

3. *The Fruit Flesh* (Fig. 253), while consisting for the most part of thin-walled, elongated or isodiametric cells with occasional starch grains (4–5 μ), is characterized by numerous clusters of strongly thickened stone cells, about which as a center radiate elongated parenchyma cells. The groups of stone cells are largest (often over 1 mm.) and occur in the greatest number in the inner layers. The individuals are isodiametric, seldom over 25 μ in diameter, or slightly elongated, and have colorless

[1] Based on the investigations of Malfatti supplemented by observations of the writer.

walls with distinctly branching pores. Alkali colors them yellow, safranin, red, thus making them evident in the mass of parenchymatous ground tissue. Similar stone cells occur in the quince, but are entirely lacking in the apple.

The inner layers of the fruit flesh belong properly to the pericarp. The transition to endocarp is more gradual than in the apple.

4. *Endocarp.* Fibers with walls thicker than the breadth of the lumen, such as form the dense endocarp of the apple, are here replaced by elongated cells with broader cavities and less strongly thickened walls.

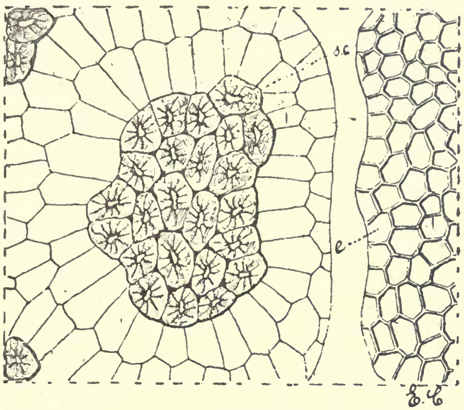


FIG. 253. Pear. *sc* group of stone cells, with radiating parenchyma, from the fruit flesh; *e* epicarp. (VILLIERS and COLLIN.)

We note in surface view the transition from large, isodiametric parenchyma cells of the fruit flesh to elongated, but broad, thick-walled, porous sclerenchyma cells, from these to narrower and thinner-walled, but distinctly porous fibrous cells, and finally to the non-porous cells of the inner layer. The parenchyma which forms in the suture bears multicellular, branching, warty hairs (Fig. 254) similar to those found in the apple, but lacking the thick-walled members.

Spermoderm. 1. *Outer Epidermis.* Since the cells are isodiametric polygonal, as seen in surface view, they may be distinguished at a glance from the longitudinally elongated, conspicuously reticulated cells of the apple. Viewed in cross section they are prismatic, upward of 50 μ high. The secondary membrane is mucilaginous in the outer portion of the cell, leaving but a narrow cylindrical cell lumen. In the inner portion of the cell this mucilaginous wall is thinner, the cavity being here bulb-shaped. The thin innermost, or tertiary membrane of the cell-wall greedily takes up safranin, thus bringing out very clearly the cell cavity, which, taken as a whole, is flask-shaped.

2. *Fiber Layer.* Eight to fourteen layers of brown-walled, strongly thickened fibers with brown contents form the bulk of the spermoderm. In cross section they are polygonal. Differentiation in the inner layers

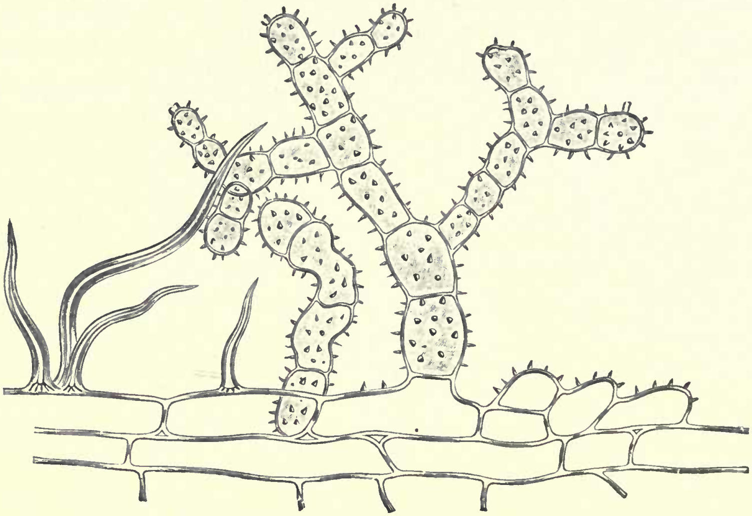


FIG. 254. Pear. Hairs from suture of endocarp. (MALFATTI.)

into tube cells such as occur in the apple, is not noticeable, the fibers passing abruptly into the cross cells of the next layer.

3. *Cross Cells,* 4. *Starch Cells,* and 5. *Inner Epidermal Cells,* also **Perisperm, Endosperm, Embryo,** and **Stem** are much the same as in the apple.

DIAGNOSIS.

Pears are preserved and dried in various ways for winter use. On the Continent, fruit of inferior grade, as well as the pomace from the manufacture of pear cider, is dried and ground for the preparation of various coffee substitutes and for adulterating spices and other food products.

The elements of value in distinguishing pears from apples are the window cells (Fig. 252) of the epidermis (smaller than in the apple); the groups of stone cells (Fig. 253) in the fruit flesh (absent in the apple); the endocarp cells with broad lumen (narrow in the apple); and the isodiametric mucilaginous epidermal cells of the spermoderm (longitudinally elongated and spirally reticulated in the apple). The warty, multicellular hairs (Fig. 254) on the sutures of the carpels are similar in both species, but those of the pear lack thick-walled members. Other conspicuous elements common to both fruits are the brown fibers and cross cells of the spermoderm, and the elements of the stem.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Hanausek, T. F. (10); Moeller (29); Schimper (37); Villiers et Collin (42); Vogl (45).

BAILLON: Sur le development des ovules des Pyrus. Bull. mens. de la soc. Linn. de Paris. 1875, **45**.

GARCIN: Recherches sur l'histogénèse des péricarpes charnus. Ann. Soc. nat. Bot. Sér. VII, 1890, **12**, 175.

HOWARD: Microscopical Examinations of Fruits and Fruit Products. U. S. Dept. Agr. Bur. Chem. Bull. **66**, 103.

JUMELLE: Sur les graines à deux téguments. B. S. B. France, 1888, **35**, 302.

MALFATTI: Beiträge zur Anatomie der Birn- und Apfelfrucht. Ztschr. Nahr.-Unters. Hyg. 1896 **10**, 265.

NEVINNY: Die Piment-Matta. Ztschr. Nahr.-Unters. Hyg. 1887, **1**, 46.

QUINCE.

The quince (*Cydonia vulgaris* Pers., *Pyrus Cydonia* L.), although regarded by some authorities as belonging to another genus, is closely related to the apple and pear. The tree is a native of central Asia, but is cultivated throughout the temperate regions of both continents.

The fruit of some varieties is apple-shaped, of others pear-shaped. Woolly hairs cover the surface of the immature fruit, but are loosely attached, and many of them either fall off during ripening or are rubbed off by handling. The fruit has five cavities, like the apple and pear, but each contains 6–15 seeds arranged mostly in two crowded rows.

HISTOLOGY.

Receptacle and Pericarp. 1. *The Epidermis* consists of window cells (10–25 μ) like those of the pear and also hairs. The latter are exceedingly crooked and usually have walls thinner than the lumen. They resemble raspberry hairs.

2. *The Hypodermal Cells* are of no special interest.

3. *Fruit Flesh.* Several authors have cited the mesocarp of the quince as one of the most striking examples of stone cells distributed through a parenchymatous tissue. The tissue is even more remarkable

than that of tne pear, as the groups of stone cells are usually larger, often reaching several millimeters in diameter, and the parenchyma cells radiating from them are usually more elongated. Small starch grains are distributed through the parenchyma.

The inner layer of the fruit flesh is properly mesocarp.

4. *The Endocarp* of the quince is similar to that of the pear, except that here and there strongly thickened fibers occur in the middle layers.

Spermoderm. 1. *Epidermis.* The gelatinous substance which surrounds the moist seeds originates in this layer. Mounted in glycerine the cellular structure is indistinct, but on addition of water the mucilaginous substance forming the inner or secondary membrane of the walls dissolves and the cells assume their normal, sharply prismatic form. The cells are often over 100 μ high and have thin colorless primary walls. In tangential section they are isodiametric polygonal, but in fragments obtained by scraping, owing to their height, they often fall on their sides and present the characteristic elongated appearance seen in cross section.

2. *Fiber Layer,* 3. *Cross Cells,* 4. *Starch Cells,* and 5. *Inner Epidermis,* agree closely in structure with the corresponding layers of the pear.

Perisperm. By treating cross sections with Javelle water, the outer cells of the compressed tissue forming the perisperm swell to their normal shape. The thick cuticle evidently belongs to these cells.

Endosperm and **Embryo** present the characters common to the group. Tschirch notes that the aleurone grains vary from 5.5–6.5 μ and contain globoids in considerable numbers.

DIAGNOSIS.

As quinces are more expensive than the other pomes, they probably never serve as adulterants. The microscopist may, however, be called upon to examine quince preserves for foreign pulp, or quince seeds (used in medicine because of their mucilaginous properties) for seeds of the apple or other foreign seeds.

The groups of stone cells in the fruit flesh are like those of the pear, and are distinguished from other stone cells by the elongated parenchyma cells, which, even after cooking, form rosettes about the groups. Mounted in water, the thin-walled, prismatic epidermal cells of the spermoderm, often 100 μ high, are unlike the epidermal cells found in the apple or pear. The crooked hairs of the epicarp resemble those of the raspberry.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Berg (3); Planchon et Collin (34); Tschirch (39).

BORDZILOWSKI: Ueber die Entwicklung der beerenartigen und fleischigen Früchte. Arb. Kiewer Naturf. Ges. 1888, **9**, 65.

GARCIN: Recherches sur l'histogénèse des péricarpes charnus. Ann. Soc. nat. Bot. Sér. VII, 1890, **12**, 175.

GODFRIN: Étude histologique sur les tégument séminaux des Angiospermes. Soc. d. Sci. d. Nancy, 1880, 109.

HOWARD: Microscopical Examinations of Fruits and Fruit Products. U. S. Dept. Agr. Bur. Chem. Bull. **66**, 103.

ALMOND.

Although the almond is commonly known as a nut, it is properly a drupe with the outer pericarp removed, or in common parlance, a "stone." The almond tree (*Prunus amygdalus* Stokes) is so closely related to the peach that some botanists regard it as but a variety of the latter developed by cultivation. According to Focke it is a native of Turkestan and middle Asia, but it is now cultivated not only in the Orient, but in southern Europe, northern Africa and California.

The cultivated varieties fall into two classes: the sweet almonds (var. *dulcis*) including the hard and the paper-shelled varieties, and the bitter almonds (var. *amara*), the latter containing a glucoside, amygdalin, which through the agency of emulsin, another constituent, splits up into dextrose, hydrocyanic acid, and oil of bitter almonds. In all the varieties, the outer pericarp at maturity is not fleshy as in the peach, but thin and leathery, splitting away from the stone along a longitudinal groove on one side of the fruit. The stone or unshelled almond is flattened, pointed at one end, of a buff color, and has a dull surface with numerous shallow pits. The outer part of the endocarp is not so hard as the inner, and is more or less separated from the latter by a zone containing the fibro-vascular bundles. Paper-shelled almonds, owing to the thin endocarp, are particularly suited for table use.

Although the ovary contains two ovules, only one usually develops into a seed (Fig. 255, *1–5*). The latter is suspended in the cavity, being connected with a large bundle running between the two layers of the endocarp. A conspicuous raphe passes from the hilum situated near the pointed or upper end of the seed to the chalaza at the lower or broader end, there separating into numerous branches. A thin brown spermoderm

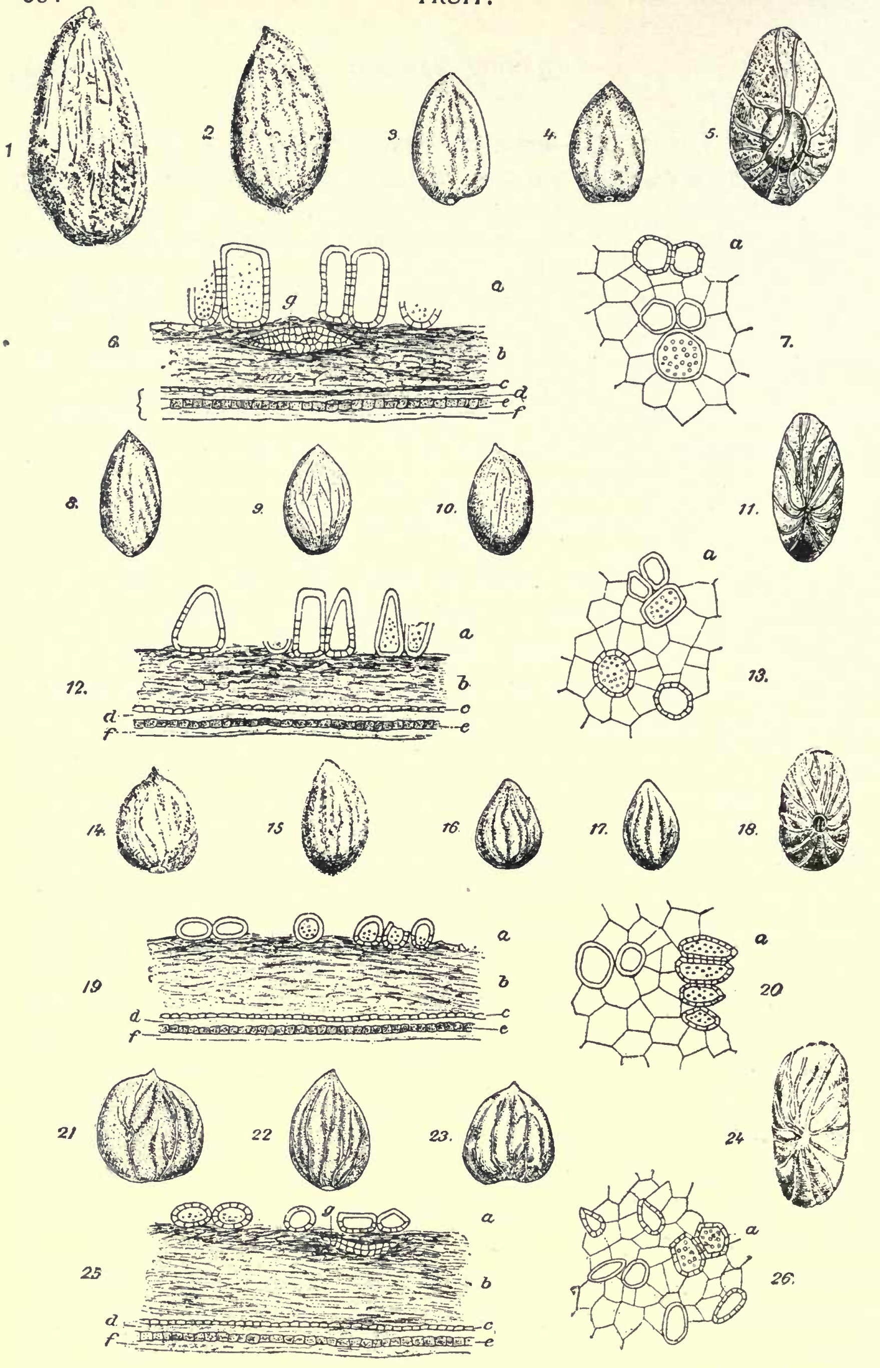


FIG. 255. Seeds of Drupes. 1–7. Almond (*Prunus amygdalus*); 8–13. Peach (*P. Persica*); 14–20. Plum (*P. domestica*); 21–26. Apricot (*P. Armeniaca*).

Side views of the seeds (1–4, 8–10, 14–17, 21–23) show variations in form and size, ×1; basal views (5, 11, 18, 24) show chalaza and nerves, ×2.

6, 12, 19, and 25. Skin in cross section. Spermoderm consists of *a* outer epidermis, *b* middle layers with *g* bundles, and *c* inner epidermis; *d* perisperm; endosperm consists of *e* aleurone cells and *f* obliterated cells.

7, 13, 20, and 6. Outer epidermis of spermoderm in surface view. (WITTMACK and

and a still thinner, colorless skin made up of perisperm and endosperm incloses the embryo, which consists of large cotyledons and a small radicle situated at the hilum end.

The highly esteemed Jordan almonds from Malaga have long, narrow kernels, with light buff, smooth spermoderm. Other varieties, including Alicanti or Valencia almonds, have broadly ovoid, flattened kernels and a rough, dark-brown spermoderm.

HISTOLOGY.

Endocarp. In the outer papery layers the ground tissue is made up of isodiametric, parenchyma and sclerenchyma cells with thickened walls pierced by circular pores. The bundles, which lie in a zone between this and the inner endocarp, contain numerous pitted vessels 10–15 μ broad and, rarely, spiral vessels.

The inner or hard endocarp is thin, being but 0.5 mm. or less thick in paper-shelled varieties. On the inner surface it is smooth but not lustrous. The cells throughout are sclerenchymatized, but vary greatly in size and shape as well as in the thickness of the walls. Those in the outer layers are large, usually isodiametric, with walls only slightly thickened. Their circular or elliptical pores are small but very conspicuous. In the middle layers the stone cells are transversely elongated and rather narrow, with walls often thicker than the breadth of the lumen. Still narrower (seldom over 20 μ), elongated stone cells form the inner layers. They are for the most part longitudinally arranged and have walls so strongly thickened that the lumen is reduced to a narrow line. All have white or light yellow walls and colorless or light brown contents.

The Spermoderm forms a thin brown skin with a finely granular outer surface. Cross sections should be examined directly in water and also after treatment with alkali, or, better still, with Javelle water.

1. *Outer Epidermis* (Fig. 255, *6*, *a*). Large stone cells with broad lumen and rather thin walls distributed in groups among the parenchyma cells characterize this layer. They reach a breadth of 100 μ and a height of 175 μ. As seen in cross section they are more or less rectangular. Circular pores penetrate the walls of the inner half.

2. *The Hypoderm* (*b*) includes two or three layers of brown polygonal cells without intercellular spaces.

3. *The Middle Layers* (*c*) are of spongy parenchyma, through which pass the raphe and its branches, consisting of numerous spiral vessels, phloem elements, and crystal fibers.

4. *Inner Epidermis* (*c*). Although made up of small cells, this layer is distinct in cross section because of the brown contents. In surface view the cells are polygonal.

Perisperm (*d*). From seeds soaked in water the perisperm and endosperm may be separated as a white inner skin. A hyaline layer of obliterated cells occurs in this as well as in the other common species of the genus. Treatment of sections with Javelle water brings out the outer layer of rectangular cells with a cuticularized outer membrane.

The Endosperm (*e*) consists of a single layer of aleurone cells with rather thick walls, and inner layers of obliterated cells.

Embryo. The epidermal cells are elongated, the cells of the inner layers rounded. The small aleurone grains of the ground tissue are 3–5 μ, the large solitary grains 10–15 μ in diameter. Some contain crystalloids, others globoids, and still others, particularly the large solitary grains, calcium oxalate rosettes.

DIAGNOSIS.

Whole Almonds. Seeds or "pits" of the peach, apricot, and plum closely resemble shelled almonds, and are common substitutes (Fig. 255). Wittmack and Buchwald, who have made comparative studies of the four seeds, find that, although the stone cells found in the epidermis of the almond and peach are commonly higher than broad, whereas in the apricot and plum they are broader than high, this distinction is of little service in identification. The characters on which they place chief dependence follow:

1. Almond. Agreeable taste, also strong odor on adding hot water, characteristic. Even bitter almonds lack disagreeably bitter taste. Spermoderm firm, leathery, light yellow-brown within.

2. Peach. Kernels broadly ovoid, flatter than those of almonds, smaller than most almonds, sharply angled. Spermoderm very thin, brown within. Taste at first somewhat sweet, afterwards bitter. Odor, after treatment with hot water, sweet.

3. Plum. Kernels rather long or broadly ovoid, thick, rounded at angles. Spermoderm as in peach. Taste like that of peach kernels, but bitter after-taste more disagreeable. Odor after scalding sweet, suggesting ripe plums.

4. Apricots. Kernels broadly heart-shaped, flat. Spermoderm firm, leathery, within white and shining. Taste same as that of peach and plum kernels. Disagreeable, sweet odor on treatment with hot water.

Almond Paste consists of the ground kernel freed from spermoderm. From it are made dietetic preparations for diabetics, also cosmetics, and macaroons, a well-known confection. Peach and apricot kernels are common adulterants, but cannot, with our present knowledge, be detected by the microscope.

Almond Cake, obtained as a by-product in the manufacture of almond oil, yields on grinding almond flour, much used as a cosmetic, also in Europe as an adulterant of ground spices and other powders. The tissues of the spermoderm, particularly the stone cells of the epidermis (Fig. 255, *7*, *a*), are of chief importance in diagnosis.

Almond Shells, like those of other fruit stones, are ground for adulterating spices. The stone cells and vascular elements are easily found, but not so easily distinguished from similar elements of other shells.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Berg (3); Collin et Perrot (9); Hanausek, T. F. (10, 16, 48); Meyer, Arthur (27); Moeller (29); Planchon et Collin (34); Vogl (45).

COLLIN: Falsification des substances alimentaires par les coques d'amandes pulvérisées. Journ. pharm. chim., 1905, 101.

GARCIN: Du noyau des drupes. Histologie et histogénèse. Ann. d. l. Soc. Bot. Lyon, 1890, **17**, 27.

GARCIN: Contributions à l'étude des péricarpes charnus. Du noyau des drupes. Histologie et histologénèse. Lyon, 1890.

GARCIN: Recerches sur l'histogénèse des péricarps charnus. Ann. Soc. nat. Bot. Ser. VII, 1890, **12**, 175.

GODFRIN: Étude histologique sur les tégument séminaux des Angiospermes. Soc. d. Sci. d. Nancy, 1880, 109.

WITTMACK u. BUCHWALD: Die Unterscheidung der Mandeln von ähnlichen Samen. Ber. deutsch. bot. Ges. 1901, **19**, 584.

PEACH.

Notwithstanding its specific name (*Prunus Persica* Sieb. et Zucc.), the peach is believed to be a native of China. It is a typical drupe, with a hairy epicarp, a fleshy mesocarp, and a dense, deeply furrowed stone or endocarp. The varieties in cultivation have yellow or white flesh, the outer portion, particularly in white peaches, often being suffused with red, as are often the fibrous layers adjoining the stone. The stone either clings to the flesh or is free. The seed (Fig. 255, *8–11*) is smaller than the almond and has a thinner spermoderm. It tastes at first sweet, afterwards bitter, and has a sweet odor after scalding.

HISTOLOGY.

Fresh or canned whole peaches may be hardened in alcohol for sectioning. The epicarp separates readily from the fully ripe fruit, especially after scalding. Sections of the stone may be prepared with a strong razor, or by grinding on an oil-stone.

Pericarp. 1. *The Epicarp* elements are polygonal cells, stomata and numerous hairs, the latter forming a dense velvety coat. These hairs are exceedingly variable in length, many being mere papillæ, while others exceed 1 mm. They are straight or slightly sinuous, 10–25 μ broad in the middle, tapering toward both ends, and are either rather sharp pointed or, less often, blunt. Even the short forms are strongly developed, the thickness of the walls usually exceeding the breadth of the lumen. The basal portions between the epidermal cells are exceedingly narrow (6–10 μ), with scarcely evident lumen. Separated from the epicarp, the hairs often appear double pointed.

2. *A Hypoderm* of 4–6 layers of tabular, somewhat collenchymatous cells is seen in cross section.

3. *Mesocarp.* The cells are for the most part rounded and present no characteristic feature. Howard finds that the vessels of the bundles are mostly reticulated, spiral vessels being absent. About the bundles the pulp cells are elongated.

4. *Endocarp.* The hard, deeply furrowed shell of the peach stone is 3–8 mm. thick, of a light brown color. Although exceedingly hard throughout, it is easily split into halves by inserting a knife-blade through the suture, thus disclosing a prominent bundle entering the cavity near its upper end. A continuation of this bundle is the funiculus. There is no separation of the endocarp by a bundle zone into an outer and inner portion as in the case of the almond, the tissues being hard and, to the naked eye, nearly uniform throughout.

The bulk of the stone is a dense aggregate of nearly isodiametric stone cells often 50–75 μ broad, with colorless, porous walls equalling or exceeding in thickness the breadth of the lumen. Within 0.5 mm. or less of the inner surface there is a layer 200–300 μ thick of narrow transversely elongated stone cells, passing abruptly into an inner layer of still narrower forms longitudinally arranged.

The Spermoderm, Perisperm, Endosperm, and Embryo conform closely in structure to the almond. Wittmack and Buchwald note that the epidermal stone cells of the peach spermoderm taper toward the free end, two neighboring cells being in contact only at the basal end (Fig. 255, *13*, *a*). In surface view this character is not evident.

DIAGNOSIS.

The Pulp or flesh is not only eaten raw, but is dried and preserved whole, and is made into preserves.

It consists of thin walled elements and bundles. The absence of spiral vessels in the bundles facilitates the detection of apple pulp, one of the commonest adulterants of fruit products. In preserves, even when made from the pared fruit, as is almost always the case, fragments of the epicarp, or more commonly the detached hairs from this coat, are present in greater or less abundance. The hairs are characterized by their variable length, thick walls, and narrow base. Detached from the epicarp they appear to be double-pointed.

The Endocarp in powder form lacks characteristic features, the colorless stone cells of other drupes and of other vegetable products having practically the same appearance.

The Seed (Fig 255) agrees so closely in structure with the almond that distinction must be based largely on physical tests (p. 336).

BIBLIOGRAPHY.

See Bibliography of Almond, p. 337: Garcin; Godfrin; Wittmack u. Buchwald.

HOWARD: Microscopical Examinations of Fruits and Fruit Products. U. S. Dept. Agr. Bur. Chem. Bull. **66**, 103.

LAMPE: Zur Kenntniss des Baues und der Entwickelung saftiger Früchte. Ztschr. Naturw. 1886, **59**, 295.

MICKO: Ueber den microskopischen Bau der Steinkerne von *Amygdalus persica, Prunus armeniaca, domestica et avium*, sowie deren Vorkommen in Genussmitteln. Ztschr. österr. Apoth.-Ver. 1893, **31**, 2, 21.

APRICOT.

The apricot tree (*Prunus Armeniaca* L.), a native of central Asia, is cultivated in various parts of Europe, also extensively in California. The fruit is a drupe, very much like the peach in macroscopic structure, the chief difference being that the stone is nearly lenticular, about 20 cm. broad, and is merely roughened on the surface by shallow pits, whereas the peach stone is deeply furrowed. On the ventral suture is a prominent keel with a sharp edge, and either side of this keel a pronounced rib. Through the stone, beneath the suture, passes the bundle which enters the locule near the apex and passes into the funiculus.

The more or less heart-shaped, flattened seed (Fig. 255, *14–18*) is but little elongated, the breadth often equaling or exceeding the length. It has a bitter after-taste, and on scalding with water a disagreeable, sweet smell.

HISTOLOGY.

In histological structure the distinctions from the peach are few and not well marked.

Pericarp. *The Epicarp, Mesocarp, and Endocarp* agree closely with the corresponding parts of the peach. Howard notes that the mesocarp bundles contain many greatly elongated, reticulated vessels, but only rarely spiral forms.

Spermoderm (Fig. 255, *25*, *26*). Wittmack and Buchwald find that the epidermal stone cells of the apricot and plum are smaller than in the almond and peach, and their height (48–60 μ) is often considerably less than their breadth (66–102 μ). As these distinctions are not always well marked and are not evident in surface view, they are regarded by these authors as of little value in distinguishing the seeds.

DIAGNOSIS.

Apricots preserved without removal of the skins and stones are identified by the hairs of the former and the shape, size and shallow-pitted surface of the latter. The epidermal stone cells of the spermoderm are smaller than in the almond and peach. Further distinctions are described under Almond.

Preserved apricots, containing neither skin nor stones, lack distinctive characters.

BIBLIOGRAPHY.

See Bibliography of Almond, p. 337, and Peach, p. 339: Howard; Micko; Wittmack u. Buchwald.

PLUM.

Numerous varieties of both the European plum (*Prunus domestica* L.) and the Japanese species (*P. triflora* Rxb.) are cultivated throughout the temperate zone. The European species includes red, blue, and white varieties, differing greatly in size and excellence. None of the Japanese varieties is blue or purple.

Plums never have a hairy epicarp, but in other respects are not strikingly different from apricots. The stone is smaller than that of the apricot and somewhat more elongated, but otherwise is very similar both in gross and minute structure (Fig. 255, *14–18*).

HISTOLOGY.

Pericarp. 1. *Epicarp.* The division of the mother cells into daughter cells is clearly evident in surface preparations. The walls are more or less distinctly beaded. In the European plum the cells are seldom over 60 μ, in the Japanese varieties still smaller, rarely exceeding 35 μ. The coloring matter of blue, red, and other colored varieties is confined entirely to the epicarp.

2. *Mesocarp.* The ground tissue is not characteristic. According to Howard, both spiral and reticulated vessels are found in the bundles.

Spermoderm (Fig. 255, *19*, *20*). The stone cells are seldom higher than broad and resemble closely those of the apricot.

Endosperm. On the broad sides of the seeds there are 15–25 layers of well-formed aleurone cells, but on the narrow sides there is but one layer.

DIAGNOSIS.

Plums are commonly dried, or preserved in a wet way, with skins and stones, thus facilitating their identification. Prunes (dried plums), are sometimes used in coffee substitutes. The stone is smaller than that of the apricot but similar in shape, external appearance, and anatomical structure. The absence of hairs on the epicarp furnishes a ready means of distinction from both the peach and the apricot.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Blyth (5); also see Bibliography of Almond, p. 337, and Peach, p. 339: Howard; Micko; Wittmack u. Buchwald.

BORDZILOWSKI: Ueber die Entwickelung der beerenartigen und fleischigen Früchte. Arb. Kiewer Naturf. Ges. 1888, **9**, 65.

CHERRY.

The sweet or Mazzard cherry (*Prunus avium* L.), a native of Europe and western Asia, also the sour or Morello cherry (*Prunus cerasus* L.), are both cultivated in numerous varieties, which are black, white, or red according to the nature of the coloring matter in the epicarp.

Like the plum, the epicarp is smooth, but the cells are noticeably larger, seldom less than 35 μ, often 100 μ in diameter; furthermore, the division of mother cells into daughter cells is not usually evident.

BIBLIOGRAPHY.

LAMPE: Zur Kenntniss des Baues und der Entwickelung saftiger Früchte. Ztschr. Naturw. 1886, **59**, 295.

ROSE FRUIT.

The "seeds," or more correctly speaking the fruits, of the dog rose (*Rosa canina* L.) and of other species of the same genus are of some importance in Europe as a drug and as a coffee substitute.

The ovoid, lustrous, red, compound fruit, the size of a small grape, consists of a closed receptacle bearing on the inner hairy surface several true fruits about as large as grape seeds. Each fruit is a dry drupe with hard pericarp hairy at the base, thin spermoderm, inconspicuous endosperm, and relatively large embryo, the structure throughout being quite similar to that of the strawberry nutlet.

HISTOLOGY.

Lacking the fruits of *Rosa canina*, the fruits of any rose may be examined, as they all agree closely in structure.

Receptacle. The polygonal outer epidermal cells with red contents, and the hairs of the inner epidermis are the important tissues. The latter often reach the length of several millimeters, have thick walls and narrow lumen, and gradually taper toward the base so that when detached they are pointed at both ends.

Pericarp. Transverse, longitudinal, and tangential sections are cut with a strong razor.

1. *The Epicarp Cells* are longitudinally elongated, and are the only cells of the pericarp that are not sclerenchymatized.

2. *Hypoderm.* One or more layers of longitudinally elongated (in cross section isodiametric), rather thin-walled cells form the hypodermal layer.

3. Large radially elongated *Stone Cells* constitute the middle layers.

4. *Longitudinal Fibers.* These fibers are distinguished in cross section from the stone cells of the preceding layer by their small diameter and isodiametric form.

5. *Transverse Fibers* in several layers are seen to advantage in cross section. Like the crossing fibers of the fourth layer they are exceedingly narrow.

Spermoderm. Cross sections cut with the pericarp should be soaked for a time in Javelle water to expand and clear the tissues. The spermoderm should also be studied in surface preparations obtained by soaking the seeds in Javelle water and scraping.

The Outer Epidermis is of polygonal cells (30–75 μ) in diameter, and *the Inner Epidermis*, of narrow (8–15 μ), transversely elongated cells of a brown color. The middle layers are either absent or obliterated.

Perisperm. This is an obliterated tissue forming a hyaline membrane on the outer cells of the endosperm.

Endosperm. One to several layers of cells containing aleurone grains, with often obliterated inner layers, constitute the thin endosperm.

The Embryo tissues are like those of the strawberry (p. 347).

DIAGNOSIS.

The epidermal cells of the receptacle with red contents, the hairs pointed at both ends, the stone cells of the pericarp, and the thin-walled cells of the spermoderm are the chief diagnostic elements.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Hanausek, T. F. (10); Villiers et Collin (42).

STRAWBERRY.

The varieties of strawberry cultivated in Europe are chiefly improved forms of *Fragaria Chiloensis* Ehrh., but some are said to be hybrids of this species with *F. vesca* L., or *F. Virginiana* Duchesne. In many parts of Europe, however, the small but delicious wood strawberry (*F. vesca* L.) is consumed in larger quantities, both fresh and preserved, than the cultivated sorts.

In colonial times the wild strawberry (*F. Virginiana*), with its several varieties, was cultivated in American gardens, but of late years has been supplanted almost entirely by the numerous derivatives of the Chilian species, although wild strawberries are still gathered in considerable quantities in the meadows. *F. vesca* grows in the northern part of the United States, but it is not so common as the Virginian species.

The cultivated strawberries (*F. Chiloensis*) are usually of large size (often 3–5 cm. in diameter), and bear the achenes in deep depressions.

Berries of the wood species (*F. vesca*) are of small size (seldom over 1 cm. in diameter) and bear the achenes in shallow depressions.

Berries of the Virginian species are of about the same size as the wood strawberries, but like the cultivated berries, the achenes are deeply sunken in the receptacle.

The receptacle, the edible part of the strawberry, consists of a somewhat fleshy pith, a still more fleshy cortex, and between the two a narrow zone of fibro-vascular bundles, from which branches shoot off through the cortex to the achenes (Fig. 256, *I*).

On the surface, the receptacle has a tufted appearance, due to the

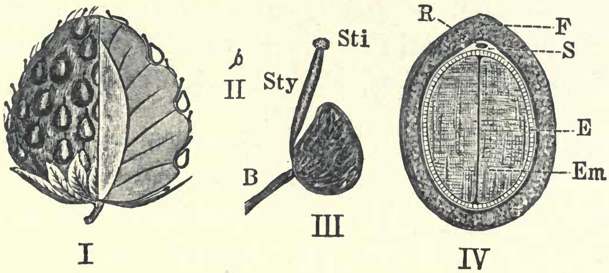


FIG. 256. Strawberry (*Fragaria Chiloensis*). *I* aggregate fruit, ×2. *II* achene, ×1. *III* achene, ×8: *Sty* style; *Sti* stigma; *B* connecting bundle. *IV* achene in transverse section, ×32: *F* pericarp; *S* spermoderm; *R* raphe; *E* endosperm; *Em* embryo. (WINTON.)

somewhat regularly arranged depressions occupied by the achenes. The epidermis is sparingly pubescent.

The achenes are ovate, pointed, about 1 mm. long (Fig. 256, *II* and *III*). Each is attached to the receptacle a little above its base, and contains a single anatropous seed, which is described as "exalbuminous," since the endosperm is not evident under the simple lens. The style (about 2 mm. long) arises from the ventral side a little above the point of attachment.

The pericarp is hard and comparatively thick; the spermoderm soft and thin; the embryo minute (Fig. 256, *IV*). When the fruit reaches maturity the calyx is still green and leaf-like, and the stamens are also well preserved. The calyx, the stamens, and a portion of the pith are removed in preparing the fruit for the table.

HISTOLOGY.

In microscopic structure the cultivated, the wood, and the Virginian strawberries are identical.

Receptacle (Fig. 257). 1. *The Epidermal Cells* (*ep*) for the most part are polygonal and isodiametric, but those radiating from the base of each hair are usually irregularly diamond-shape, and often strongly elongated. The hairs are not numerous, but are often over a millimeter long, tapering gradually from the widest part near the base to the point (*h*). In the basal portion the lumen is several times the thickness of the walls, but narrows somewhat abruptly further on, and for fully three-fourths of the total length of the hair is but a narrow channel

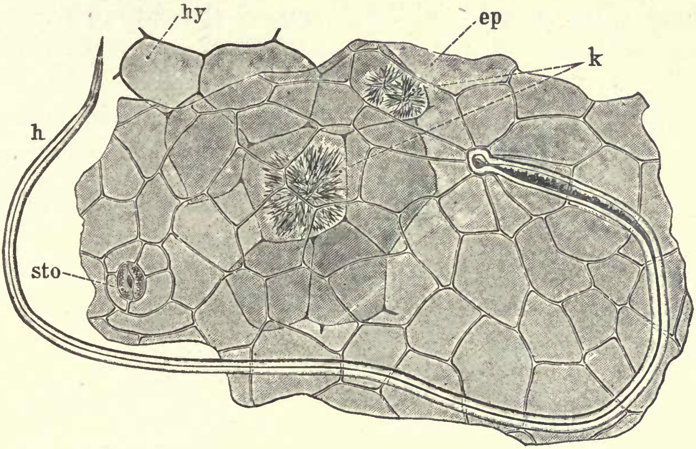


FIG. 257. Strawberry. Receptacle in surface view. *ep* epidermis with *h* hair and *sto* stoma; *hy* hypoderm; *k* glucoside (?) crystals. ×160. (WINTON.)

hardly one-quarter as wide as the walls. The walls, on the other hand, are narrowest at the basal end. Stomata occur sparingly.

2. *Hypoderm or Sarkogen Layer* (*hy*). Tschierske has shown that the fleshy receptacle of the strawberry owes its origin to a hypodermal layer of meristematic cells, which are mostly tangentially elongated, and are always without intercellular spaces. These cells, to which he gives the name "sarkogen layer," resemble the phellogen or cork-forming cells of other plants, but differ in that the new cells are formed centripetally and remain active during the whole period of growth, whereas the cork cells are formed centrifugally and die soon after formation. The cells increase in size in radial directions, and divide by tangential partitions. After they have performed their mission they continue to increase in size, but hold to their original shape.

3. *Cortical Tissue.* The daughter cells formed by the division of the cells of the sarkogen layer increase rapidly in size, become round in shape, and form intercellular spaces. This tissue forms the bulk of the ripe fruit. Each cell is rich in contents, which, on cooking or treatment with alcohol, yield a shriveled, opaque mass.

4. *Bundles.* Spiral and annular vessels from 5–10 μ in diameter, and thin-walled, elongated cells, are the conspicuous elements of the bundles.

5. *Pith.* Large berries often contain large intercellular spaces or cavities in the pith, formed by the tearing asunder of the cells during the rapid growth.

Pericarp (Fig. 258). 1. *Epicarp* (*epi*). In surface view, the cells are polygonal, 15–50 μ in diameter, with thin walls. The cuticle is several times as thick as the radial walls of the cells.

2. *Mesocarp* (*mes*). This layer is strikingly different from the mesocarp of most edible fruits in that it is not succulent, and consists of only

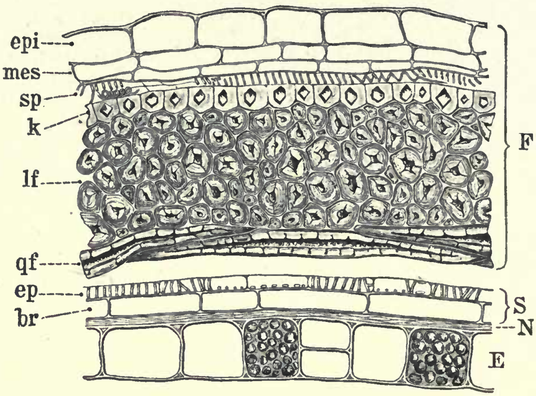


FIG. 258. Strawberry. Achene in transverse section. *F* pericarp consists of *epi* epicarp, *mes* mesocarp, *sp* spiral vessels, *k* crystal layer, *lf* outer endocarp with longitudinally extended fibers, and *qf* inner endocarp with transversely extended fibers; *S* spermoderm consists of *ep* epidermis with reticulated cells, and *br* elongated brown cells; *N* perisperm; *E* endosperm consists of a single layer of aleurone cells. ×300. (WINTON.)

one, or in some parts two, cell-layers. In cross section the cells have much the same appearance as the epidermal cells, but usually have smaller dimensions. On the inner side are numerous bundles, the branches of which run transversely about the achene.

3. *Crystal Layer* (*k*). The cells are polygonal, 8–20 μ in diameter. The monoclinic crystals are always simple.

4. *Outer Endocarp* (*lf*). This layer, forming the larger part of the pericarp, is made up of five or more thicknesses of sclerenchyma fibers longitudinally arranged. The cell-walls are distinctly porous and about as thick as the lumen.

5. *The Inner Endocarp* (*qf*) consists of the same elements as the outer endocarp, but is only one or two cell-layers thick, and the cells are arranged transversely. On the dorsal side some of the fibers of this layer extend radially through the outer endocarp, thus facilitating the rupture of the pericarp during sprouting.

Spermoderm (Figs. 258 and 259). 1. *The Epidermis* (*ep*) is of thin-walled polygonal cells. The cell-walls are exceedingly thin, but are strengthened by spirally reticulated bands, which do not pass completely around the cell, but are wanting on the outer surface, so that in mounting a preparation the outer wall often collapses and the side walls fall down, presenting the appearance shown in Fig. 259.

2. *Brown Layer* (*br*). The second layer of the spermoderm is composed of transversely elongated brown cells, often arranged side by side

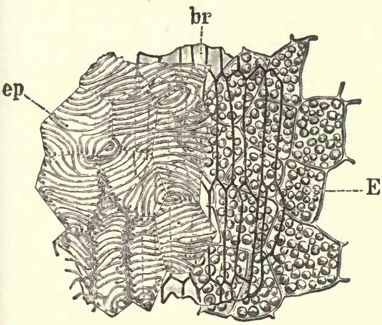


FIG. 259. Strawberry. Spermoderm and endosperm in surface view. *ep* reticulated epidermis of spermoderm; *br* brown cells; *E* endosperm. ×300. (WINTON.)

FIG. 260. Strawberry. Style and stigma. ×32. (WINTON.)

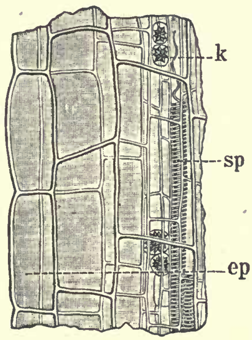


FIG. 261. Strawberry. Style in surface view. *ep* transparent epidermis; *sp* spiral vessels; *k* crystal cells. ×300. (WINTON.)

in rows. They vary up to 100 μ in length, and usually between 10–15 μ in width.

Perisperm (*N*). This coat consists for the most part of obliterated cells forming a cellulose layer from 2–4 μ thick, but on the ventral side the cells are often well defined.

Endosperm (*E*). This consists of a single layer of aleurone cells.

Embryo. Two large cotyledons, each in cross-section semielliptical, make up the bulk of the embryo. The thin-walled cells contain protein and fat but no starch.

Style and Stigma (Figs. 260 and 261). The strawberry style is distinguished from the styles of other edible rosaceous fruits by its constricted base and the large size and transparency of the epiderm cells. It is about 0.3 mm. in diameter in the middle part, but tapers somewhat toward the stigma, and very markedly toward the base, where it is less than 0.1 mm. in diameter. The epidermal cells (*ep*) are for the most part about 40 μ wide, 100–150 μ long, and (as may be seen on the margins, by focusing) 50 μ thick. The central core appears darker than the transparent margins, owing to the greater density of the parts as well as to the greater thickness. Treatment with alkali discloses spiral and annular vessels, also rows of accompanying crystal cells (*k*), each containing a crystal rosette.

Fungous growths often completely hide the papillæ of the stigma, even after treatment with reagents or cooking.

DIAGNOSIS.

Styles and achenes may be readily picked out with forceps and examined as to their size and shape under a lens. The styles (Figs. 260 and 261), transparent in the fresh fruit, and rendered still more so by the boiling with sugar, may be studied under the compound microscope without further treatment. Their size (2 mm. long), narrow base and large transparent epidermal cells, are especially characteristic; but the spiral vessels accompanied by crystal clusters, and the stigma, often bristling with fungous threads, further aid in the identification. Crystals are clearly differentiated by the aid of polarizing apparatus.

For the study of the pericarp and seed, cross sections (Fig. 258) should be prepared, holding the achene between pieces of soft wood or in a hand-vice during the cutting. Especially striking are the two crossing endocarp layers of sclerenchyma fibers, the endosperm of a single cell layer, and the relatively large embryo. The reticulated cells of the outer layer of the spermoderm are highly characteristic.

The hairs (Fig. 257, *h*) of the receptacle are characterized by their length (often 1 mm.) and narrow lumen.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Blyth (5).

KRAUS: Ueber den Bau trockner Pericarpien. Pringsh. Jahrb. 1866, **5**, 83.

MARPMANN: Beiträge zur mikroskopischen Untersuchung der Fruchtmarmeladen. Ztschr. angew. Mikr. 1896, **2**, 97.

TSCHIERSKE: Beiträge zur vergleichenden Anatomie und Entwicklungsgeschichte einiger Dryadeenfrüchte. Ztschr. Naturwissenschaft. 1886, **59**, 594.

WINTON: Beiträge zur Anatomie des Beerenobstes. Ztschr. Unters. Nahr.-Genussm. 1902, **5**, 785. Conn. Agr. Exp. Sta. Rep. 1902, 288.

RED RASPBERRY.

Rubus Idæus L. occurs native in various part of the Old World and is the parent of the raspberries cultivated in European gardens.

Bailey[1] states that the red raspberries cultivated in America are offspring of the native *R. strigosus* Michx., which, however, is closely related to the European raspberry *R. Idæus* L. The yellow varieties are but albino forms of these species.

The raspberry, blackberry, and other bramble fruits (*Rubus*) are intermediate in both macroscopic and microscopic structure between the strawberry (*Fragaria*) and the stone fruits (*Prunus*). They resemble the strawberry in that they are aggregate fruits with numerous individual fruitlets on a common receptacle (although unlike the strawberry, the cortex of the receptacle is not fleshy and bears the fruitlets on elevations, not in depressions); and they resemble the stone fruits in the structure of the pericarp and seed, each individual fruitlet being in fact a minature drupe. The resemblance between the raspberry drupelet and the peach is especially striking. In both the epicarp is pubescent, the mesocarp is fleshy, the endocarp (Fig. 262, *III*

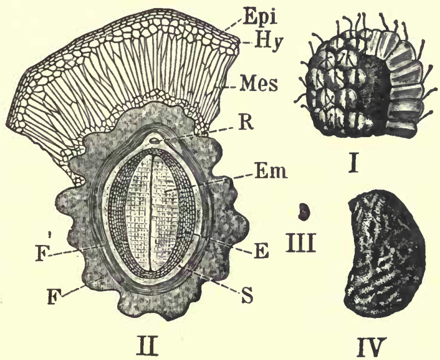


FIG. 262. Red Raspberry (*Rubus strigosus*). *I* aggregate fruit, ×1. *II* cross section of a drupelet, ×32: *Epi* epicarp; *Hy* hypoderm; *Mes* mesocarp; *F* outer endocarp; *F′* inner endocarp; *S* spermoderm; *R* raphe; *E* endosperm; *Em* embryo. *III* stone, ×1. *IV* stone, ×8. (WINTON.)

and *IV*) is a hard stone with wrinkles on the surface and the united spermoderm and endosperm form a thin coat for the relatively large embryo. They are also very similar in minute structure, as is noted further on.

[1] The Evolution of Our Native Fruits. London, 1898, 287.

The drupelets are crowded together on the top and sides of the receptacle, each having a convex top or exposed surface and four to seven facets on the sides formed by the pressure of the adjoining drupelets (Fig. 262, *I*). These facets are usually slightly convex or concave. Owing to their crowded arrangement the thickness of the flesh in the sides of the drupelets is much less than in the outer part. The exposed surface and the angles between the facets are pubescent, the facets themselves glabrous. In picking a raspberry the drupelets separate from the receptacle, clinging together in the form of a cup. Tschierske states that the individuals cling together, first because of the closely fitting adjoining facets, the slightly convex surface of one fitting into a corresponding concave surface of another, and second because of the interlocking of the crooked hairs. The style is about 4 mm. long and arises from the upper edge of the exposed surface of the drupe, appearing to come from between the drupelets.

HISTOLOGY.

Receptacle. 1. *The Epidermis* resembles somewhat the epicarp of the fruit, but the hairs are less numerous and usually thicker walled.

2. *Cortex.* As no sarkogen layer is developed in the raspberry the cortex layer is thin, the bulk of the receptacle being pith.

3. *Bundles.* It follows from what has been stated that the main bundles run near the surface of the receptacle. They are shorter and more strongly developed than in the strawberry, with larger and more numerous vessels.

4. *The Pith* consists of round parenchyma cells, devoid of cell-contents, with intercellular spaces.

Pericarp. 1. *The Epicarp* (Fig. 262, *Epi*; Fig. 263) on the facets of the drupelets consists entirely of polygonal cells, but on the exposed surfaces consists of polygonal cells and hairs, the hairs often being so numerous that they occur at two to four of the angles of the polygonal cells. Five or six cells frequently meet at the base of a hair, forming a rosette about it. The hairs vary greatly in length, up to 700 μ, and are seldom over 10 μ broad. Most of them have thin walls (0.5 to 1.5 μ) of nearly uniform thickness (*h*); but some of the longer forms have thick walls and a narrow lumen resembling the strawberry hair (*h'*). The thin-walled hairs are commonly sinuous.

2. *Hypoderm* (Fig. 262, *Hy*). Two or more cell-layers of collen-

chyma form the hypoderm, a water tissue serving to retard the evaporation of the fruit juice.

3. *Mesocarp* (Fig. 262, *Mes*). The outer two or three layers of the mesocarp consist of isodiametric cells with intercellular spaces, interspersed with crystal cells; but further inward, at least in the thicker portion of the fruit, the cells are enormously elongated in radial directions and are without intercellular spaces. Tschierske points out that the succulent nature of the fruit results from the radial growth of cells, not as in the strawberry from the formation of numerous isodiametric cells by a meristematic layer.

As in all the species of *Rubus*, cells with crystal clusters are common,

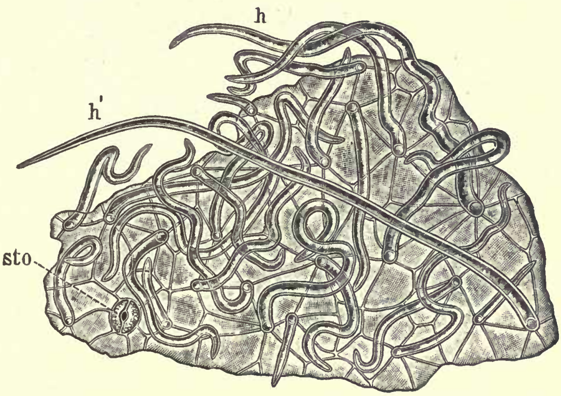


FIG. 263. Red Raspberry. Epicarp with *h'* straight hair, *h* sinuous hairs, and *sto* stoma. ×160. (WINTON.)

particularly near the base of the style. Reticulated cells occur in the inner layers adjoining the endocarp.

4. *Outer Endocarp* (Fig 262, *F*; Fig. 264, *lf*). Owing to the deep wrinkles, the thickness of this coat is exceedingly variable. As in the strawberry, the sclerenchyma fibers are longitudinally arranged and cross those of the inner endocarp at right angles. The fibers are a little narrower than in the latter fruit and in cross sections are usually elliptical polygonal, with the longer diameters in radial directions.

5. *Inner Endocarp* (Fig. 262, *F'*; Fig. 264, *qf*). The fibers of this coat, of which there are four or more thicknesses, are the same as in the outer endocarp, but run transversely about the fruit.

Spermoderm (Fig. 264, *S*). The seed coats of the bramble fruits resemble closely those of the stone fruits, the chief difference being that the epidermal stone cells are wanting.

1. *Epidermis* (*ep*). The cells are polygonal in surface view, the average diameter being 35 μ and the maximum 70 μ. In transverse section they are cushion-shaped, with a cuticularized outer wall.

2. *Nutritive Layer* (*p*). The cells in this layer, having fulfilled their mission, are empty and are often more or less collapsed.

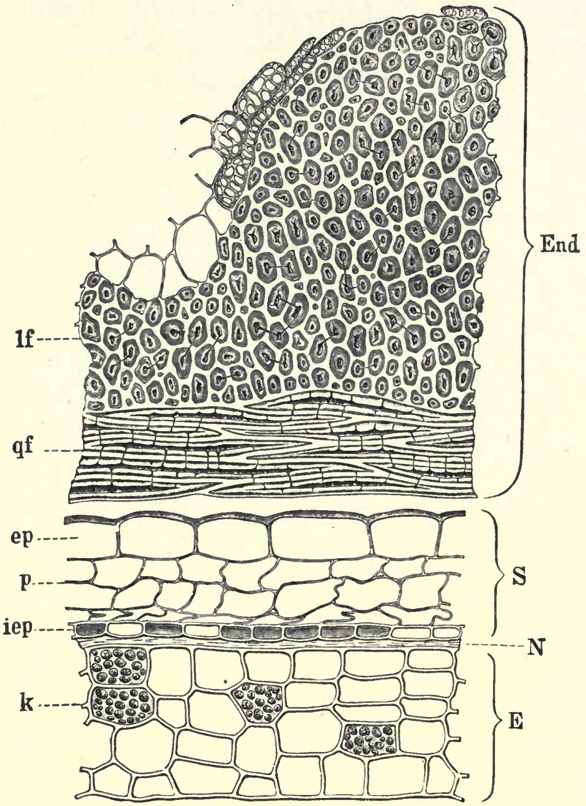


FIG. 264. Red Raspberry. Endocarp and outer portion of seed in cross section. *End* endocarp consists of *lf* longitudinally extended fibers and *qf* transversely extended fibers; *S* spermoderm consists of *ep* epidermis, *p* parenchyma (nutritive layer), and *iep* inner epidermis; *N* perisperm; *E* endosperm with *k* aleurone grains. $\times 300$. (WINTON.)

3. *Brown Layer* (*iep*). The inner layer of the spermoderm consists of cells of the same kind as in the outer epidermis, but only about half as large, the maximum diameter in surface view being 30 μ and the average 20 μ. These cells are readily distinguished from those of the neighboring layer by their thicker walls and yellow-brown color.

Perisperm (Fig. 264, *N*). As in the strawberry, all that remains of this tissue is the layer of obliterated cells, which in section appears as the thickened outer wall of the endosperm.

The Endosperm (Fig. 264, *E*) is made up of aleurone cells with remnants of other cells adjoining the embryo. On the two broader sides of the elliptical section there are five or six cell-layers, but the number diminishes toward both the ventral and dorsal sides, where there are only two or three.

Embryo (Fig. 262, *Em*). The structure of the embryo is practically the same as in the strawberry.

Style (Figs. 265 and 266). 1. *The Epidermal Cells* (*ep*) are much smaller than in the strawberry, and owing to numerous wrinkles on the surface are not so transparent. These wrinkles may be brought out clearly either by treating specimens with iodine as recommended by Tschierske, or better, by bleaching with Javelle water and staining with safranin. On the broadened basal portion of the style are scattering hairs like those of the epicarp.

2. *Bundles*. After heating the style with dilute alkali, the vessels (*sp*) and accompanying isodiametric crystal cells (*k*) are clearly evident.

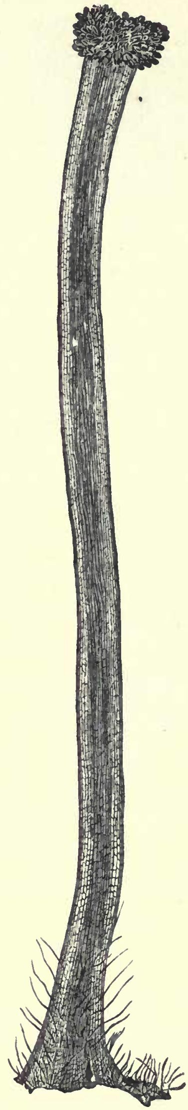


FIG. 265. Raspberry. Style and stigma. ×32. (WINTON.)

DIAGNOSIS.

Styles and stones (seeds with inclosing endocarp) are evident to the naked eye.

The styles (Figs. 265 and 266) may be examined directly under the microscope as in the case of the strawberry, and are identified by their length (4 mm.), broadened base with hairs, and small, wrinkled epidermal cells. Vessels and crystal cells are also striking elements.

The stones (Fig. 262, *III*, *IV*) are distinguished from seeds of other genera by their characteristic wrinkled surface and from blackberry stones by their smaller size. Cross sections (Fig. 264) show the two layers of endocarp, the spermoderm with cells of the outer epidermis twice the diameter of those of the inner epidermis, the endosperm of several cell layers, and the embryo.

The epicarp (Fig. 263), the hairs of which are mostly blunt, narrow (10 μ), thin-walled and sinuous, also the crystal cells of the underlying mesocarp, may be readily found in mounts prepared from the gelatinous portion of the product. The hairs are easily distinguished from those of the peach and apricot which are broad (10–25 μ), nearly straight, and have walls thicker than the breadth of the lumen. Vascular elements are almost entirely wanting, as the receptacle is not picked with the fruit.

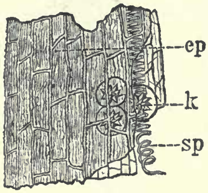


FIG. 266. Raspberry. Style in surface view. *ep* epidermis; *sp* spiral vessel; *k* crystal cells. ×300. (WINTON.)

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Villiers et Collin (42).

MARPMANN: Beiträge zur mikroskopischen Untersuchung der Fruchtmarmeladen. Ztschr. angew. Mikr. 1896, **2**, 102.

TSCHIERSKE: Beiträge zur vergleichenden Anatomie und Entwickelungsgeschichte einiger Dryadeenfrüchte. Ztschr. Naturwissenschaft. 1886, **59**, 612.

WINTON: Beiträge zur Anatomie des Beerenobstes. Ztschr. Unters. Nahr.-Genussm. 1902, **5**, 785. Conn. Agr. Exp. Sta. Rep. 1902, 288.

BLACK RASPBERRY.

Rubus occidentalis L., a native of the northern United States, is the parent of the black varieties. It differs from the red raspberry chiefly in the smaller size of the drupelets and their deep purple-black color, due to the dark claret-red cell juice. The pits of both are about the same size and shape.

The black raspberry has practically the same microscopic structure as the red species.

Black raspberry jam or preserve is of a deep claret-red color and the seeds are stained the same color.

BLACKBERRY.

Rubus fruticosus grows wild in various parts of Europe, but is seldom cultivated.

In North America three native species are of importance: the tall blackberry (*R. nigrobaccus* Bailey), the short cluster blackberry (*R. nigrobaccus* var. *sativus* Bailey), and the dewberry, or running blackberry (*R. villosus* Aiton). These are not only common wild plants, but have given rise to numerous cultivated varieties.[1]

[1] Bailey: The Evolution of our Native Fruits. London, 1898, 366, 379.

In macroscopic and microscopic structure the berries of all the species named are practically alike.

The blackberry agrees with the raspberry in general structure, but differs in the following details: (1) The drupelets are glabrous or, in

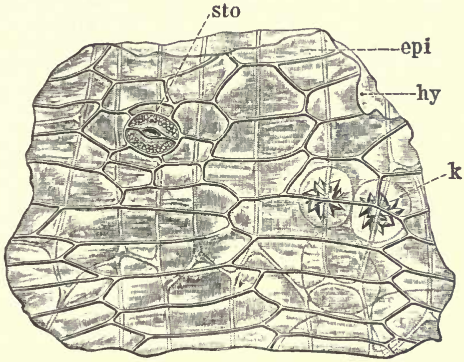


FIG. 267. Blackberry (*Rubus nigrobaccus*). Outer layers of pericarp in surface view. *epi* epicarp with *sto* stoma; *hy* hypoderm; *k* crystal cells. ×160. (WINTON.)

the case of the dewberry, sparingly hairy. (2) The drupelets are firmly attached to the receptacle by broad bases and do not separate from the latter on picking the fruit. There is really no epidermis of the receptacle as the surface is almost completely covered by the bases of the drupelets, the epicarp of one being continuous with that of the adjoining drupelet. (3) As may be seen from Fig. 268, the pits resemble those of the raspberry in shape and markings, but are much larger. (4) The styles (Fig. 269) are but 2 mm. long and commonly arise from a marked depression in the drupelet. They are free from hairs and do not broaden at the base.

FIG. 268. Blackberry. Stone, ×1 and ×32. (WINTON.)

HISTOLOGY.

Receptacle. The structure of the receptacle differs in no essential detail from that of the raspberry.

Pericarp (Fig. 267). 1. *Epicarp* (*epi*). The cells are for the most part elongated, the longer diameters extending in latitudinal directions on the sides of the drupelets, and in concentric circles about the styles. Stomata are always present, hairs never in *R. nigrobaccus*, seldom in *R. villosus*.

2. *Hypoderm* (*hy*). As in the epicarp, the cells are commonly elongated, but are much larger and extend in longitudinal directions.

3. *Mesocarp*. This layer is much the same as in the raspberry. Crystal clusters (*k*) are numerous, especially near the surface.

4. *Endocarp*. As in the raspberry, the sclerenchymatized fibers of the endocarp have secondary and tertiary membranes and run longitudinally in the outer, and latitudinally in the inner layer. Both coats, however, are thicker than in the raspberry, the inner consisting of 6–10 cell-layers.

FIG. 269. Blackberry. Style and stigma. ×32. (WINTON.)

Spermoderm. It has been noted that the outer epidermis of the raspberry spermoderm is made up of polygonal cells with about twice the diameter of those in the inner epidermis. The reverse is true in the case of the blackberry, the spermoderm being much the same as a raspberry spermoderm turned inside out. The average diameter of the outer epidermal cells is about 25 μ, the maximum 40 μ, whereas the average diameter of the inner epidermal cells is 40 μ and the maximum 60 μ.

Style (Fig. 269). The epidermal cells are about the same size as in the raspberry, but are not wrinkled to any appreciable extent. Hairs are entirely wanting. Crystals and vessels are conspicuous in alkali preparations.

DIAGNOSIS.

Examination of blackberry preserves is made as described under raspberry. Styles (Fig. 269) are less numerous than in the latter and are distinguished by their shorter length, and the absence of hairs and wrinkles. In cooked products it is not usually evident that the styles arise from a depression in the drupelet. The seeds (Fig. 268) are larger than in raspberries, but in histological structure are very similar. They are, however, distinguished from the latter by the thicker inner endocarp and by the fact that the cells of the outer epidermis of the spermoderm are about half the diameter of those of the inner epidermis; whereas, in the raspberry the reverse is true. In blackberry preserves, unlike that made from raspberries, hairs are few or entirely absent; but tissues of the receptacle, notably the vascular elements, are present.

Compared with the strawberry, the bundles are shorter but more strongly developed, with larger and more numerous vessels. Elongated epidermal cells and crystal clusters are also distinguishable.

BIBLIOGRAPHY.

GODFRIN: Etude histologique sur les tégument séminaux des Angiospermes. Soc. d. Sci. d. Nancy, 1880, 109.

LAMPE: Zur Kenntniss des Baues und der Entwickelung saftiger Früchte. Ztschr. Naturw. 1886, **59**, 295.

WINTON: Beiträge zur Anatomie des Beerenobstes. Ztschr. Unters. Nahr.-Genussm. 1902, **5**, 785. Conn. Agr. Exp. Sta. Rep. 1902, 288.

SAXIFRAGACEOUS FRUITS (*Saxifragaceæ*).

The bush fruits of this family yield many-seeded berries, with withered remains of the floral parts at the extremity. The epicarp is either smooth (red currant), glandular (black currant), or prickly (some species of gooseberry). Only in the currants is the endocarp sclerenchymatized. The seeds are characterized by the large inflated epidermal cells, and the crystal layer of the spermoderm, the bulky thick-walled endosperm containing aleurone grains, and the minute embryo.

RED CURRANT.

Both the red and white garden varieties of currant are derived from the European species, *Ribes rubrum* L.

The calyx tube is united with the ovary, and the fruit (a true berry) bears on the summit the shriveled remains of the floral parts (Fig. 270, *I*). The deeply five-cleft bell-shaped calyx tube bears in its throat five petals much smaller than the calyx lobes and alternating with them, and five stamens opposite the lobes. The short style, about half the length of the calyx, is deeply two-cleft. The midribs of each of the floral envelopes, ten in number, are continued in the fruit in the form of longitudinal veins and are clearly seen through the transparent epicarp. The anatropous seeds, one to eight in number, are borne on two parietal placentæ (Fig. 270, *II*). As a result of the crowded arrangement they are usually flattened on one or more sides. The outer spermoderm (Fig. 270, *III*, *S*) is gelatinous and transparent, and through it may be seen the delicate thread-like raphe and the brown hard inner spermoderm. The minute embryo (Fig. 270, *III*, *Em*) is embedded in the base of the endosperm.

Divested of the gelatinous coat the seeds are from 4 to 5 mm. long and from 3 to 4 mm. broad (Fig. 270, *IV* and *V*).

HISTOLOGY.

Pericarp (Fig. 271). 1. *Epicarp* (*epi*). In parts the walls are thickened with narrow pores; in other parts the walls are not thickened at

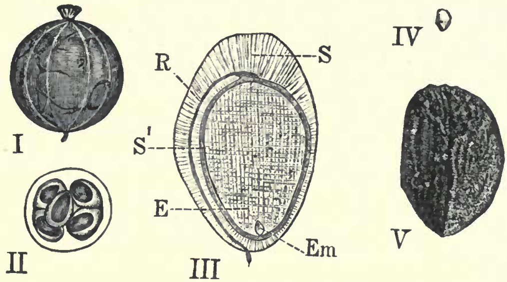


FIG. 270. Red Currant (*Ribes rubrum*). *I* fruit, ×1. *II* cross section of fruit with seeds, ×1. *III* longitudinal section of seed, ×8: *S* gelatinous epidermis of spermoderm; *S'* inner spermoderm; *R* raphe; *E* endosperm; *Em* embryo. *IV* seed deprived of gelatinous coat, ×1. *V* same as *IV*, ×8. (WINTON.)

all, or only here and there. Frequently strongly beaded cells are divided by thin partitions into two daughter cells. Stomata are numerous. Cross sections show that the cells are considerably broader than thick.

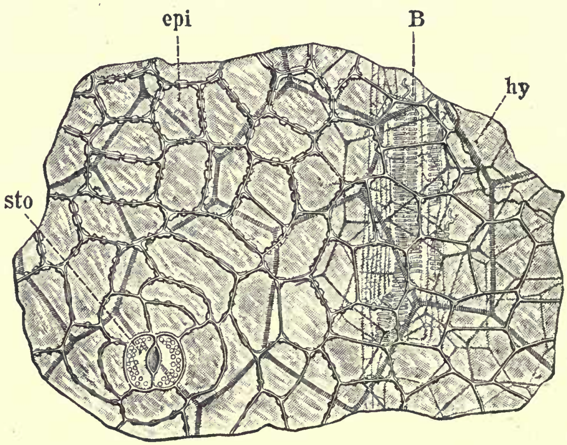


FIG. 271. Red Currant. Outer layers of pericarp in surface view. *epi* epicarp with *sto* stoma; *hy* hypoderm; *B* vascular bundle or vein seen through the transparent outer layers of the fruit. ×160. (WINTON.)

2. *Hypoderm* (*hy*). Two or three cell layers of collenchymatous cells underlie the epidermis. In surface view they are polygonal with diam-

eters twice or more those of the epidermal cells. Their collenchymatous character is seen in a cross section.

3. *Mesocarp.* The cells are isodiametric (100–300 μ), with thin walls and numerous intercellular spaces. Radiating from the bundles are elongated cells. Crystal rosettes abound in the inner layer.

4. *Endocarp* (Fig. 272). Unlike the gooseberry, the currant has a sclerenchymatous endocarp. The long cells are arranged in groups, each

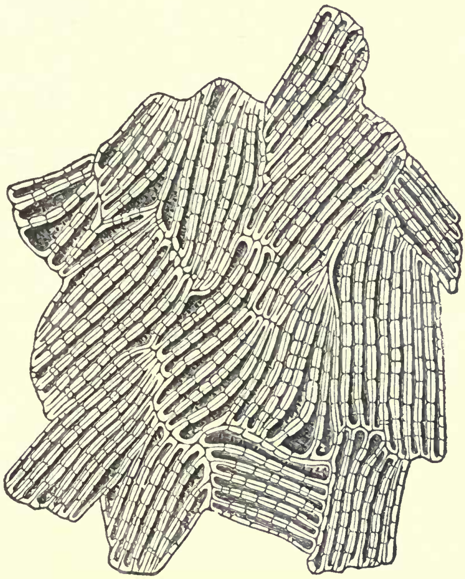


FIG. 272. Red Currant. Endocarp in surface view. ×160. (WINTON.)

group consisting of five to fifteen cells side by side. The cells of adjoining groups may extend either in the same or different directions. Curious fan-shaped forms result from the junction of several groups. As a rule the cavity is much thinner than the walls and oftentimes is reduced to a mere line. Numerous pores connect adjoining cells and some pierce the walls separating these cells from the mesocarp. The cells range in length up to 500 μ; the thickness of the double walls is 5–20 μ.

Spermoderm (Fig. 273, *S*). 1. *Mucilage Cells* (*aep*). The outer layer consists of large, thin-walled cells filled with gelatinous matter. They are about 90 μ in tangential diameter but often have a radial diameter of over 500 μ. On the outer surface they are usually convex. Owing to the great size of the cells, this coat, although but a single cell-layer thick, forms a considerable part of the bulk of the seed.

2. *Parenchyma* (*p*). Beneath the mucilage cells are several layers of more or less flattened parenchymatous cells with intercellular spaces. The cells of the inner layers are smaller and flatter than in the outer.

3. *Crystal Layer* (Figs. 273 and 275, *k*). In surface view the deep brown, thick-walled cells of this layer are sharply polygonal with diam-

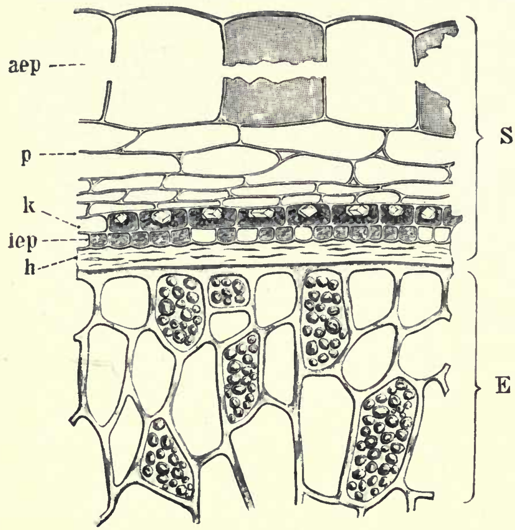


FIG. 273. Red Currant. Seed in cross section. *S* spermoderm consists of *aep* gelatinous outer epidermis, *p* parenchyma (nutritive layer), *k* crystal layer, and *iep* brown layer (inner epidermis); *N* perisperm; *E* endosperm. $\times$300. (WINTON.)

eters from 8 to 20 μ. The middle lamella is colorless, the thick membrane, brown. Each cell contains a single monoclinic crystal, which nearly or completely fills the cell cavity.

With crossed Nicol prisms these crystals appear as luminous spots in the black background, disappearing on addition of a drop of hydrochloric acid. In section it may be seen that only the radial and inner walls are thickened, and that as a consequence each crystal lies close to the thin outer wall.

4. *Inner Epidermis* (Figs. 273 and 275, *iep*). Like the crystal layer, the inner epidermis is of a deep-brown color, but this color is due to cell-contents, not to thickened cell-walls. The cells are longitudinally elongated, varying in length up to 150 μ and in width from 4 to 9 μ. Both this layer and the crystal layer are readily separated from the endosperm by soaking in dilute alkali and scraping.

Perisperm (Fig. 273, *N*). A cross section of the seed shows a cellulose band about 10 μ thick between the spermoderm and the endosperm, consisting of the obliterated cells of the nucellus.

The Endosperm (Figs. 273 and 275, *E*) consists of thick-walled cells containing aleurone grains and fat. In the outer layers the cells are radially elongated, with walls of even thickness (2 μ), but in the center of the seed they are isodiametric, often with knotty thickened walls (Fig. 274).

DIAGNOSIS.

Cells of the endocarp (Fig. 272) are the most conspicuous and characteristic elements of preserves. Fragments of the epicarp and floral parts are also evident but are of less value in identification. The outer gelatinous coat of the seed is destroyed by cooking, but the crystal layer and the inner epidermis retain their original form and may be identified in surface mounts (Fig. 275) prepared by warming in dilute alkali and scraping with a scalpel. Sections of the seed are sometimes useful, but as a rule an examination of the spermoderm in surface view is sufficient.

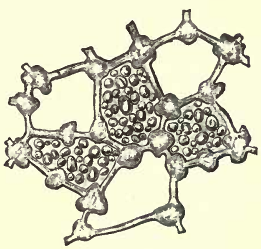


FIG. 274. Red Currant. Cross section of central portion of endosperm. ×300. (WINTON.)

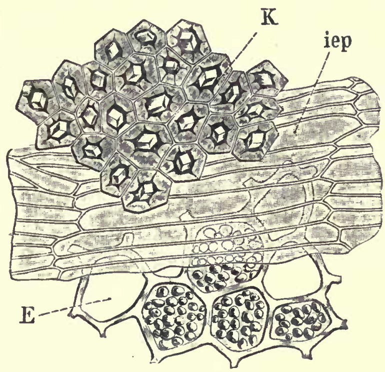


FIG. 275. Red Currant. Surface view of *K* crystal layer, *iep* inner epidermis of spermoderm, and *E* endosperm. ×300. (WINTON.)

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Blyth (5); Villiers et Collin (42).

GARCIN: Recherches sur l'histogénèse des péricarpes charnus. Ann. Soc. nat. Bot. Sér. VII, 1890, **12**, 175.

LAMPE: Zur Kenntniss des Baues und der Entwickelung saftiger Früchte. Ztschr. Naturwissenschaft. 1886, **59**, 295.

WINTON: Beiträge zur Anatomie des Beerenobstes. Ztschr. Unters. Nahr.-Genussm. 1902, **5**, 785. Conn. Agr. Exp. Sta. Rep. 1902, 288.

BLACK CURRANT.

The Black Currant (*Ribes nigrum* L.), a native of the Old World, is cultivated both in Europe and America.

In external appearance the fruit is distinguished from the red currant by its black color and by the longer floral parts. The seeds are somewhat smaller and more numerous (about 15 in each berry) than in the red varieties.

The calyx is about 7 mm. long, and the lobes are reflexed. On the outer surface and on the inner surface at the ends the lobes are clothed with numerous hairs; but the throat is smooth, as are also the petals and the style. The latter is entire for at least three-fourths its length, but two-lobed at the end.

HISTOLOGY.

The cells of the *Epicarp* (Fig. 276, *epi*) are beaded and of about the same size as in the red currant. Here and there are bright-yellow disc-

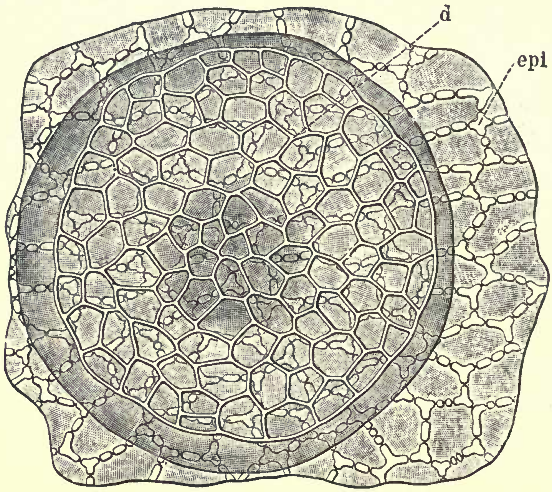


FIG. 276. Black Currant (*Ribes nigrum*). *epi* epicarp with *d* gland, in surface view. ×160. (WINTON.)

shaped glands (*d*) which often exceed 170 μ in diameter. Meyen noted that they occur in still greater numbers on the leaves, and that they agree in structure with the glands of the hop. Each gland consists of a single layer of cells in the form of a disc, joined in the middle to the epicarp by means of a short several-celled stalk. The yellow oily secretion to which the plant owes its characteristic odor and flavor is contained in the reservoir formed by the separation of the outer cuticle from the cells.

The *Mesocarp*, *Endocarp*, and *Seed* have the same general structure as the same parts of the red currant.

Under the microscope the calyx hairs have the same appearance as those on the epicarp of the raspberry. They are crooked, blunt-pointed, thin-walled, and vary in length up to 600 μ.

DIAGNOSIS.

Black currant preserves, jams, etc., have a red-black color, and the characteristic spicy flavor of the fresh fruit. They are further distinguished from similar products made from red currants by the glands on the epicarp (Fig. 276,) the longer floral parts, the hairs on the outer surface of the calyx, and the smaller seeds.

The mesocarp, endocarp, and seed tissues of the red and black currant are the same in structure.

BIBLIOGRAPHY.

LAMPE: Zur Kenntniss des Baues und der Entwickelung saftiger Früchte. Ztschr. Naturw. 1886, **59**, 295.

MEYEN: Secretionsorgane d. Pflanzen. Berlin, 1837.

WINTON: Beiträge zur Anatomie des Beerenobstes. Ztschr. Unters. Nahr.-Genussm. 1902, **5**, 785. Conn. Agr. Exp. Sta. Rep. 1902, 288.

GOOSEBERRY.

The European or prickly gooseberry (*Ribes Grossularia* L.) is one of the most valuable small fruits cultivated in Great Britain and the Continent, but is seldom grown in America owing to the mildew to which it is there subject. The varieties cultivated in the United States are largely derived from a smooth fruited native species, *R. oxyacanthoides* L.

The fruit has much the same general structure as the currant, but is larger (1 to 2 cm. in diameter), the calyx and style are longer (6 mm. in length), and are pubescent, and the smooth or prickly pericarp is thicker (Fig. 277). The gelatinous coat of the seed is thicker (often 2 mm. thick on the raphe side), but the seed freed from this coat is about the same size as in the currant, although somewhat narrower and more nearly terete. Except for the prickles, the European and American gooseberry are identical in structure.

HISTOLOGY.

Pericarp. 1. *The Epicarp Cells* are polygonal and more or less beaded like those of the red currant.

The Prickles have a broad base and are often over 1 mm. long. Some have a blunt point, others, a head of globular form. Both forms are shown in Fig. 278.

The Epidermal Cells of the prickles are elongated, and are arranged end to end in longitudinal rows. At the base they pass into the isodiametric cells of the epicarp.

2. *The Hypoderm* is the same as in the red currant.

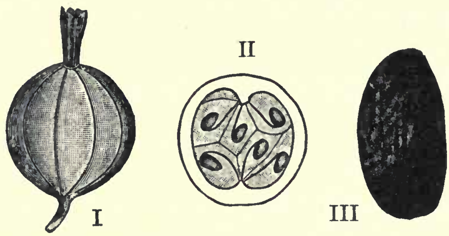


FIG. 277. American Gooseberry (*Ribes oxyacanthoides*). *I* whole fruit, ×1. *II* transverse section of fruit with seeds, ×1. *III* seeds deprived of gelatinous coat, ×8. (WINTON.)

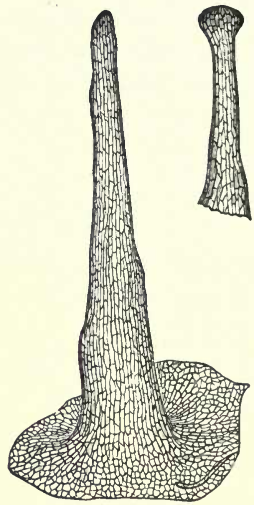


FIG. 278. European Gooseberry (*Ribes Grossularia*). Prickles with and without globular head. ×32. (WINTON.)

3. *Mesocarp.* This layer is composed of extraordinarily large cells (often 500 μ in diameter), which are evident to the naked eye and are separated from each other by a network of cells hardly 50 μ in diameter. In the inner layers the small cells are less numerous or entirely lacking. Crystal clusters are abundant, particularly in the inner layers.

4. *The Endocarp* consists of a layer of parenchyma cells with walls so thin that they are studied with difficulty, and is quite different from the sclerenchymatous endocarp of the currants.

Spermoderm, Endosperm, and **Embryo.** The microscopic structure of the seed is practically the same as that of the currant seed.

Floral Parts (Fig. 279). The remains of the floral parts are usually deep brown, and can be studied to advantage only after bleaching, preferably with Javelle water, and staining. A prominent midvein runs from the base almost to the apex of each of the calyx and corolla lobes. About four secondary veins branching near the base, partly from the calyx midrib, partly from the corolla midrib, also run nearly to the apex of the calyx lobes. Lateral branches from the midribs are numerous in the corolla, less so in the calyx.

The epidermal cells of the calyx are for the most part slightly elon-

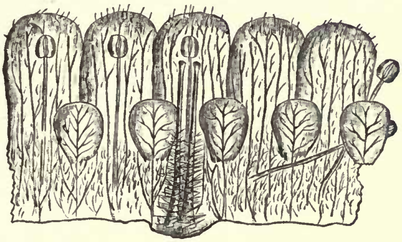


FIG. 279. Gooseberry. Floral parts. ×5. (WINTON.)

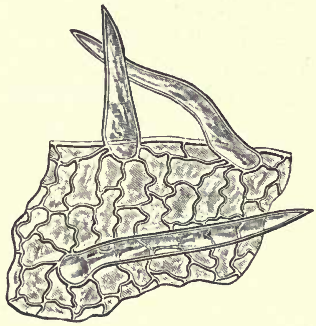


FIG. 280. Gooseberry. Epidermis from margin of calyx, with hairs. ×160. (WINTON.)

gated, and are arranged end to end in longitudinal rows. Near the ends of the lobes they have wavy outlines. The outer surface of the calyx and the upper part of the inner surface bear only a few scattering hairs. The calyx throat, however, is densely pubescent. These hairs are all thin-walled, and vary in length up to 1 mm. or more, the longest being in the calyx throat (Figs. 280 and 281).

The deeply parted styles are covered with epidermal cells, for the most part quadrilateral and arranged end to end in rows, and on the lower half bear numerous thin-walled hairs 1 mm. or more in length.

DIAGNOSIS.

The epidermis, mesocarp, and seed have the same structure as the corresponding parts of the currant, but the endocarp is not sclerenchymatized and is not evident in preserves. The floral parts (Fig. 279) are of about the same length as in the black currant (6 mm.), but the calyx throat and the styles bear numerous long hairs (Fig. 281), whereas these parts in the black currant are smooth, or only sparingly pubescent.

FIG. 281. Gooseberry. Epidermis from throat of calyx, with hair. ×160. (WINTON.)

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Blyth (5).

GARCIN: Recherches sur l'histogénèse des péricarpes charnus. Ann. Soc. nat. Bot. Sér. VII, 1890, **12**, 175.

MARPMANN: Beiträge zur mikroskopischen Untersuchung der Fruchtmarmeladen. Ztschr. angew. Mikr. 1896, **2**, 97.

WINTON: Beiträge zur Anatomie des Beerenobstes. Ztschr. Unters. Nahr.-Genussm. 1902, **5**, 785. Conn. Agr. Exp. Sta. Rep. 1902, 288.

ERICACEOUS FRUITS (*Ericaceæ*).

The fruits are either several-celled berries, each cell containing a number of seeds (cranberry, blueberry), or ten-celled drupes (huckleberry).

The smooth epicarp bears short triangular calyx teeth. Groups of stone cells occur in the mesocarp of the huckleberry, but are lacking in the mesocarp of the other species. The endocarp in the cranberry is of thin-walled elements; in the blueberry, of thin-walled cells interspersed with groups of stone cells; in the huckleberry, of a dense mass of stone cells. The spermoderm of the cranberry and blueberry is characterized by the elongated, thick-walled, porous cells.

CRANBERRY.

Bailey[1] states that the cranberry (*Vaccinium macrocarpon* Ait.), the most unique of American horticultural products, was first cultivated, or rescued from mere wild bogs, about 1810. The varieties now known are over a hundred, all having been picked up in bogs, and the annual product in the United States is more than 800,000 bushels.

The cowberry, or mountain cranberry, *Vaccinium Vitis-Idæa* L., is gathered in great quantities in Canada, where it is used for sauces. It is also a native of Europe, where it is much prized as a culinary fruit.

Different varieties of the cultivated cranberry vary in shape (spherical, oval, pear-shaped), in color (pink, red, maroon, mottled), and in size (diameter up to 15 mm.).

The epicarp is smooth, and bears on the summit four short tooth-like calyx lobes, which are usually bent inward. Between the calyx lobes

[1] The Evolution of Our Native Fruits. London, 1898, 414, 424.

is a circular spot with a dot in the center, formed by the dropping of the floral parts (Fig. 282, *I*).

The berry is four-celled, each cell containing on a central placenta a number of seeds which fill only a small part of the otherwise empty cavity (Fig. 282, *II*).

In the nearly ripe fruit only the epicarp is colored, the other parts being white; but in the fully ripe fruit all the tissues are usually red.

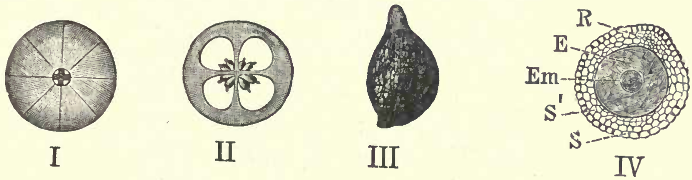


FIG. 282. Cultivated Cranberry (*Vaccinium macrocarpon*). *I* berry seen from above, ×1. *II* cross section of berry, ×1. *III* seed, ×8. *IV* cross section of seed, ×15: *S* epidermis of spermoderm; *S'* inner spermoderm; *R* raphe; *E* endosperm; *Em* embryo. (WINTON.)

The yellow short-beaked seeds have a thick spermoderm and a bulky endosperm in the axis of which is an elongated embryo of moderate size, consisting chiefly of the radicle (Fig. 282, *III* and *IV*).

The mountain cranberry has practically the same macroscopic structure as the cultivated species, but is much smaller.

HISTOLOGY.

The following description applies to both the cultivated and the mountain cranberry, the two being nearly, if not quite, identical in microscopic structure.

Pericarp. 1. *The Epicarp* (Fig. 283) is very simple in structure, with cells as seen in surface view from 20 to 50 μ in diameter, and cell-walls 3 μ thick. Cross sections show that this layer is about 25 μ thick and that the cuticle is strongly thickened.

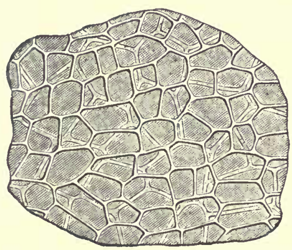


FIG. 283. Cultivated Cranberry. Epicarp and hypoderm. ×160. (WINTON.)

2. *The Hypoderm* (Fig. 283) is for the most part only one cell-layer thick, and the cells are more or less isodiametric in cross-section. Evaporation is largely prevented by the thick cuticle, rendering a more strongly developed hypoderm unnecessary.

3. *The Mesocarp* cells are mostly isodiametric, and range up to

200 μ in diameter, but in the partitions between the fruit cavities they are somewhat smaller.

4. *Endocarp* (Fig. 284). The cells are for the most part longitudinally extended and are more or less curved or wavy in outline. The in-

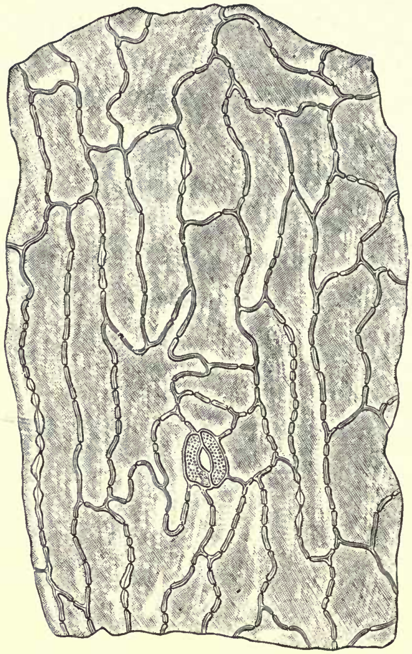


FIG. 284. Cultivated Cranberry. Endocarp with stoma. $\times 160$. (WINTON.)

distinctly porous cell-walls are somewhat thicker than those of the mesocarp, but unlike those in some *Vaccinium* species are not conspicuously thickened. Although stomata are entirely lacking in the epicarp, they occur in considerable numbers in the endocarp.

Spermoderm. 1. *Epidermis* (Fig. 285, *ep*; Fig. 286). Of all the tissues, this is the most characteristic and remarkable. The cells in the mature seed range in width up to 100 μ, and in length up to 400 μ, but in abortive seeds are much smaller. As is seen in cross section, the outer walls (Fig. 285, *ep*) are thin and convex, but the deep-yellow or brown inner and radial walls are sclerenchymatously thickened (double walls often 20 μ), and in addition the radial walls and sometimes the outer and inner walls have a transparent mucilaginous layer of distinctly stratified structure which nearly fills the cell cavity. Treated with chlor-zinc iodine the mucilaginous formation is stained blue, the cell-walls proper remaining yellow. In *V. Vitis-Idæa* the outer and inner walls often have a swollen layer (Fig. 287). The sclerenchymatous radial

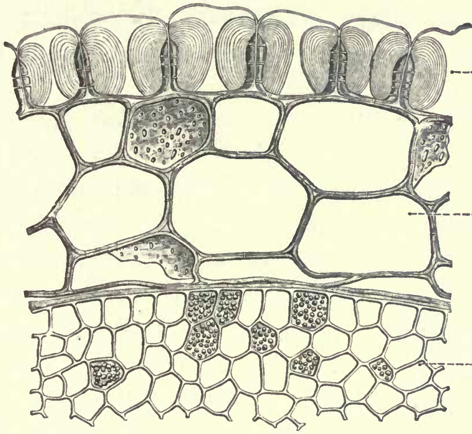


FIG. 285. Cultivated Cranberry. Seed in cross section. *ep* epidermis of spermoderm with sclerenchymatized and mucilaginous layers; *m* inner spermoderm; *E* endosperm. ×160. (WINTON.)

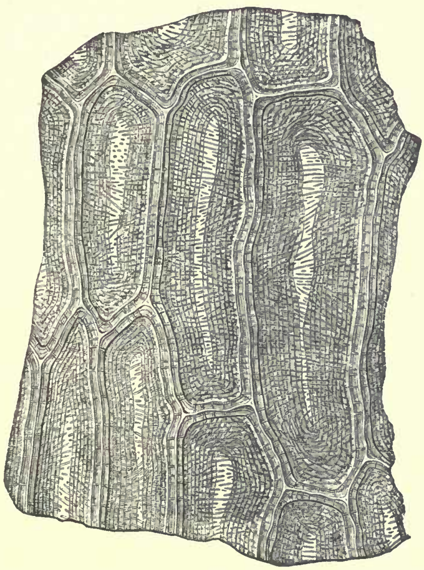


FIG. 286. Cultivated Cranberry. Epidermis of spermoderm in surface view. ×160. (WINTON.)

and inner walls are pierced with numerous pores which, in the immature or abortive seeds, are nearly circular, but in the fully ripe seeds are usually much elongated.

2. *Inner Layers* (Fig. 285, *m*). The remainder of the spermoderm consists of two or three layers of large thick-walled porous cells, the innermost layers being more or less collapsed. In dried or cooked specimens, all of these cells are collapsed.

The Endosperm (Fig. 285, *E*) contains aleurone grains but no starch.

The Embryo is not remarkable.

DIAGNOSIS.

Fragments of the epicarp (Fig. 283) and endocarp (Fig. 284), bundles from the mesocarp, and seeds, may be found in preserves. The large porous epidermal cells of the spermoderm, with sclerenchymatized and mucilage layers are characteristic and may be studied in surface preparations (Fig. 286). In unripe or abortive seeds these cells are smaller, thinner-walled, and have pores more nearly round than in the mature seeds. Isolated stone cells detached from the spermoderm of immature seeds by cooking, sometimes occur in the gelatinous portion of the preserve.

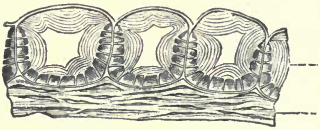


FIG. 287. Mountain Cranberry (*Vaccinium Vitis-Idæa*). Cross section of spermoderm. ×160. (WINTON.)

BIBLIOGRAPHY.

WINTON: Beiträge zur Anatomie des Beerenobstes. Ztschr. Unters. Nahr.-Genussm. 1902, 5, 785. Conn. Agr. Exp. Sta. Rep. 1902, 288.

BLUEBERRY.

Vaccinium Myrtillus L. grows over an extended area in Europe, and the berries are used both as food and as medicine.

Among the American species yielding edible berries similar to those of the European species are the tall or swamp blueberry (*V. corymbosum* L.) and two dwarf species (*V. Pennsylvanicum* Lam. and *V. Canadense* Kalm.), all of which are being introduced into cultivation.

The berries of all the species named are black with a gray-blue bloom, globular, 1 cm. or less in diameter, and are crowned by five calyx teeth. Except for the bloom they are hardly distinguishable in external appearance from the huckleberry, which they further resemble in flavor, but in internal structure the two fruits have little in common. The dense endocarp tissue of the huckleberry is represented in the blueberry by a thin and soft, although partially sclerenchymatized, tissue; furthermore, the locules of the former fruit contain but one seed, whereas in the latter they are several-seeded. On the other hand, the blueberry and cranberry, although strikingly different in color and flavor, are very similar both in gross and minute anatomy.

HISTOLOGY.[1]

The important European and American species have practically the same structure.

Pericarp. 1. *The Epicarp* consists of polygonal cells like those of the cranberry, but the contents are dark violet instead of red.

2. *The Hypoderm* of collenchyma cells is of no special interest.

3. *Mesocarp* (Fig. 288). The cells are for the most part thin-walled, but here and there, especially near the bundles, the walls are sclerenchymatized without being greatly thickened. Thick-walled stone cells, such as occur in the mesocarp of the huckleberry, are entirely wanting. Crystal clusters abound in the inner layers.

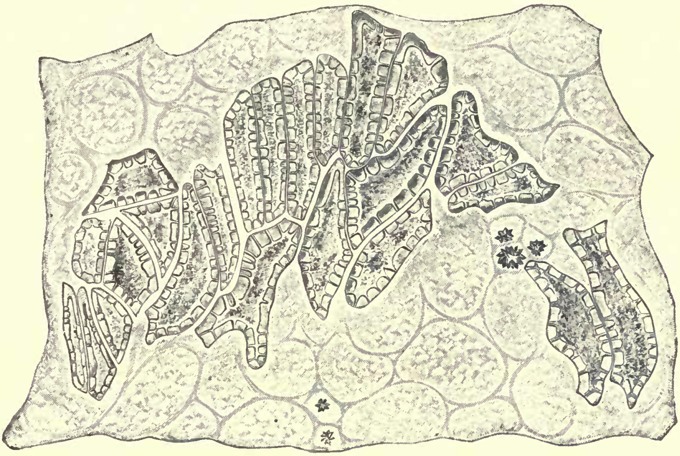


FIG. 288. Blueberry (*Vaccinium Myrtillus*). Endocarp and mesocarp in surface view. (R. MÜLLER.)

4. *Endocarp* (Fig. 288). This tissue, consisting of a single thin layer of loosely united stone cells, is intermediate between the parenchymatous endocarp of the cranberry on one hand, and the thick stone-cell tissue of the huckleberry endocarp on the other. These stone cells separate readily from one another and are remarkable for their diversity of size

[1] Based largely on R. Müller's exhaustive paper on the histology of the European blueberry.

and shape. Elongated cells, 15–50 μ in breadth, usually predominate, although isodiametric forms are also common. Among the elongated cells are distorted L-, S-, and Y-shaped, as well as various grotesque, forms. Quite as variable are the isodiametric cells, which are triangular, quadrilateral, rounded, or exceedingly irregular with curious horn-like projections.

Spermoderm. 1. *The Outer Epidermis* (Fig. 289) is of large elongated cells, the inner halves of which are strongly sclerenchymatized

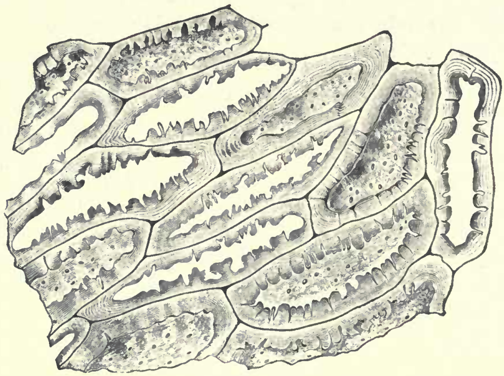


FIG. 289. Blueberry. Epidermis of spermoderm in surface view. (R. MÜLLER.)

and porous. Except for the absence of the mucilaginous inner layers of the walls, the structure is like that of the corresponding coat of the cranberry;

2. *The Middle Layers* are of parenchyma cells, and

3. *The Inner Layers* of obliterated elements forming in cross section a hyaline band.

Endosperm and Embryo contain aleurone grains and fat.

DIAGNOSIS.

The epidermis of polygonal cells, the curious stone cells of the endocarp (Fig. 288), and the whole seeds with the sclerenchymatized epidermis (Fig. 289), are easily found in preserves and similar products. The absence of large stone cells in the mesocarp and of a dense endocarp inclosing each seed, as well as the structure of the seed itself, distinguishes the fruit from the huckleberry, while the dark color of the cell-contents and the presence of the curious endocarp stone cells furnish a ready means of distinction from the cranberry.

BIBLIOGRAPHY.

GARCIN: Recherches sur l'histogénèse des péricarpes charnus. Ann. Soc. nat. Bot. Sér. VII, 1890, **12**, 175.

LAMPE: Zur Kenntniss des Baues und der Entwickelung saftiger Früchte. Ztschr. Naturw. 1886, **59**, 295.

MÜLLER U BLAU: Fructus Myrtilli. Pharm. Post, Wien. 1902, **35**, 461.

HUCKLEBERRY.

This wild berry (*Gaylussacia resinosa* Torr. and Gray) is abundant in the northern United States, and furnishes large quantities of fruit for the market.

The fruit is globular in form, blue-black in color, and 1 cm. or less in diameter (Fig. 290, *I* and *II*). It is not a true berry, but a ten-celled drupe, the hard coverings of the so-called seeds being the inner walls of the pericarp cells. The epicarp is smooth and the fruit is crowned with five-pointed calyx lobes much like those of the cranberry. In the center, between these lobes, is a small depression, the scar of the style. The pits are closely crowded about the axis, and as a consequence are wedge-shaped (Fig. 290, *III* and *IV*). Under the hand lens they have a rough granular appearance.

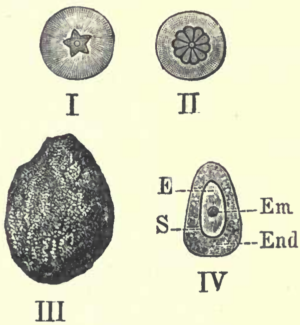


FIG. 290. Huckleberry (*Gaylussacia resinosa*). *I* fruit seen from above, ×1. *II* cross section of fruit, ×1. *III* stone, ×8. *IV* cross section of stone, ×8: *End* endocarp; *S* spermoderm; *E* endosperm; *Em* embryo. (WINTON.)

Within the thick endocarp is the seed with a thin spermoderm and a bulky endosperm; in the axis of the endosperm is an elongated embryo.

HISTOLOGY.

Pericarp. 1. *Epicarp* (Fig. 291, *epi*). Surface mounts show the cells of this layer to be much the same in form and size as those of the cranberry epicarp; cross sections, however, show that the cuticle is much thinner.

2. *The Hypoderm* (*hy*) is several cell layers thick, and thus furnishes a protection against evaporation, which is not necessary in the case of the cranberry, owing to its thick cuticle.

3. *Mesocarp* (*mes*). Owing to the presence of numerous stone cells (*st*) this layer is strikingly different from the mesocarp of the other com-

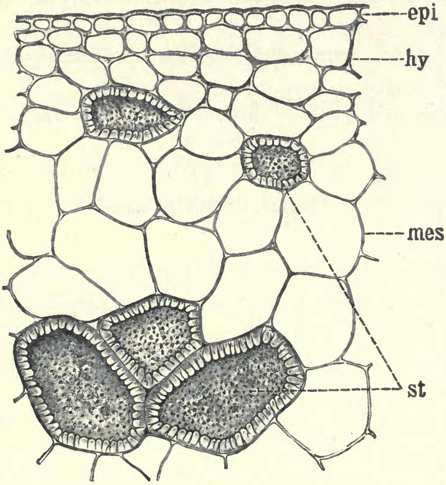


FIG. 291. Huckleberry. Cross section of outer portion of the pericarp. *epi* epicarp; *hy* hypoderm; *mes* mesocarp; *st* stone cells. ×160. (WINTON.)

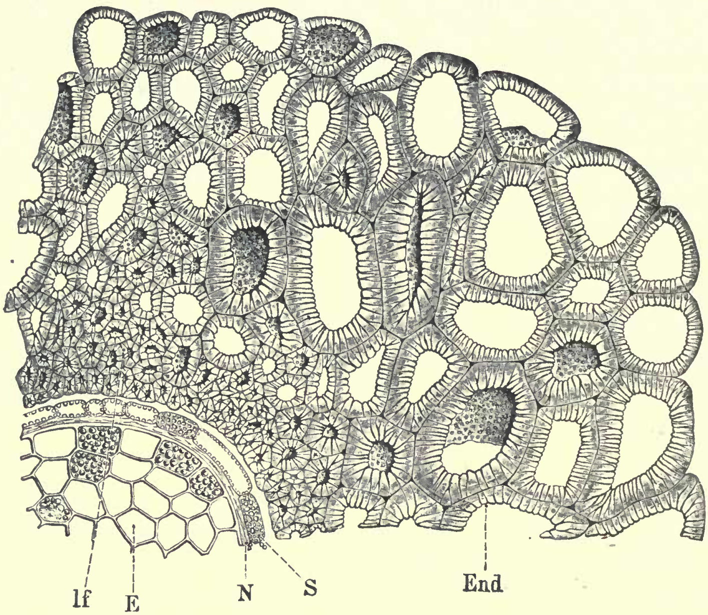


FIG. 292. Huckleberry. Cross section of endocarp and seed. *End* endocarp with large isodiametric stone cells and *lf* narrow longitudinally extended fibers; *S* spermoderm; *N* perisperm; *E* endosperm. ×160. (WINTON.)

mon small fruits, but resembles that of the quince and pear, although the stone cells are thinner-walled and the parenchyma cells about them are not strongly elongated, and are not arranged in a marked radiating pattern. These stone cells are angular or elliptical and vary in diameter up to 200 μ. The walls (20 μ or less thick) are pierced with numerous small pores. They occur either singly or in groups throughout the mesocarp, and may be readily separated from the soft tissues by pressure.

4. *Endocarp* (Fig. 292, *end*). Most of the elements of this hard coat are stone cells, about the same size and shape as those of the mesocarp (although usually thicker-walled), but in the wall adjoining the mesocarp there is a group of narrow sclerenchyma fibers running parallel

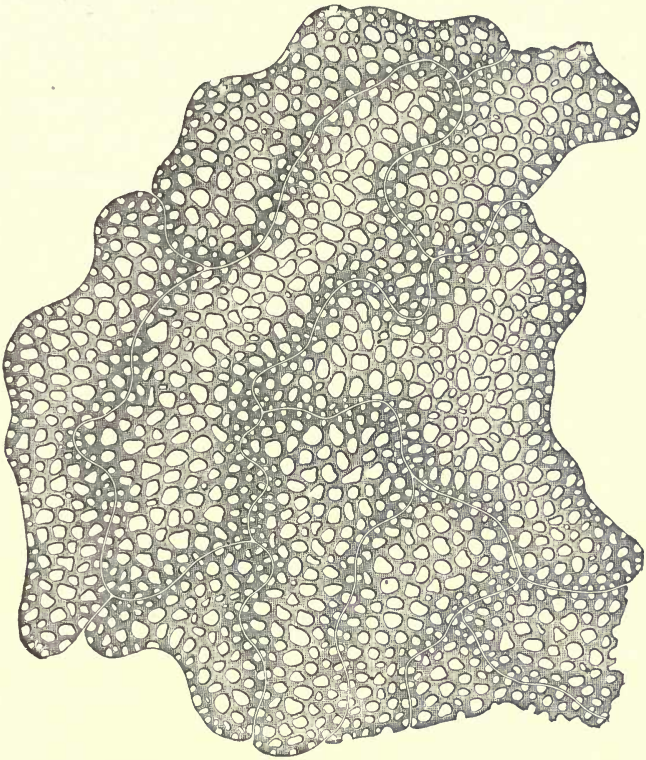


FIG. 293. Huckleberry. Spermoderm in surface view. $\times$ 300. (WINTON.)

with the axis of the fruit and similar fibers form the inner layer of the coat.

The pits of the huckleberry crush more readily between the teeth than those of the bramble fruits, owing to the larger size of the stone cells and the relatively larger cell cavities.

Spermoderm (Fig. 292, *S*). There is but one layer of cells in this coat, which may be removed after cutting off the endocarp and studied in surface view (Fig. 293). Most of the cells are of fantastic form with wavy outline, and often reach a length of 200 μ. The walls are beautifully reticulated, the nearly circular pores being 4 μ in diameter. This coat is highly characteristic. The raphe is not conspicuous.

The Endosperm (Fig. 292, *E*) and **Embryo** are much the same in structure and form as those of the cranberry.

DIAGNOSIS.

The characteristic elements of the huckleberry which may be found in preserves are the large stone cells of the mesocarp (Fig. 291) and endocarp (Fig. 292), and the reticulated cells (Fig. 293) of the spermoderm. Stone cells of the mesocarp are distributed throughout the preserve, but those of the endocarp are obtained in transverse sections of the "seeds." The spermoderm is best seen in surface preparations.

BIBLIOGRAPHY.

WINTON: Beiträge zur Anatomie des Beerenobstes. Ztschr. Unters. Nahr.-Genussm. 1902, 5, 785. Conn. Agr. Exp. Sta. Rep. 1902, 288.

CITRUS FRUITS (*Rutaceæ*).

The fruits of this family are many-seeded berries differing in size and flavor but much alike in structure. The following detailed description of the orange suffices for an understanding of the group.

ORANGE.

The orange (*Citrus Aurantium* L.) is the most valuable citrus fruit and may be styled the apple of subtropical regions. It was introduced into Europe from the Far East at an early period and thence into America in colonial times. Before the days of rapid transportation the fruit was unknown in cooler regions except as a greenhouse product; now, however, it is on sale throughout the civilized world.

Two marked varieties are recognized, the common sweet orange (var. *Sinensis* Engler) and the bitter orange (var. *amara* L.).

The fruit is a berry with normally 10 two-seeded locules, but as a result of cultivation the number of locules varies from 6–12 and the number of seeds also varies, being entirely absent in the navel varieties. The outer rind is of a deep orange color and consists of epicarp, hypoderm, and outer mesocarp. In this tissue are numerous cavities, often over 1 mm. in diameter, in which is secreted an essential oil consisting largely of a terpene, limonene, with small amounts of citral and other substances. The pimples on the surface of the fresh fruit, becoming depressions on drying, mark the position of these cavities. The inner rind or inner mesocarp is white and of much the same texture as blotting-paper. Each of the segments of the fruit is covered by a membranous skin, the endocarp, while the fleshy part is made up of club-shaped vesicles springing from the inner surface of that portion of the endocarp adjoining the rind. Each of the seeds consists of two or more (maximum 12) embryos inclosed within a skin consisting of spermoderm, perisperm, and remnants of endosperm. Owing to the mucilaginous outer layer of the spermoderm the seeds are slimy.

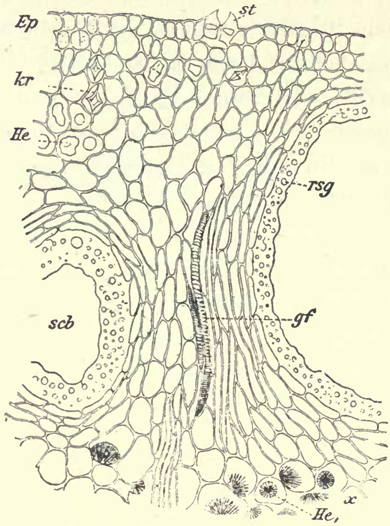


FIG. 29 . Orange (*Citrus Aurantium*). Cross section of outer layers of peel from an unripe fruit. *Ep* epicarp with *st* stoma; *scb* oil cavity; *gf* fibro-vascular bundle; *kr* crystals of calcium oxalate; *He* lumps and crystals of hesperidin. (TSCHIRCH and OESTERLE.)

HISTOLOGY.

Fresh ripe oranges are usually obtainable at all seasons and in all countries. Lacking these, alcoholic material may be used, and with the advantage that the tissues are hardened and the crystals of hesperidin are better defined.

Pericarp (Fig. 294). Transverse and tangential sections of the rind and surface mounts of the skin covering the segments should be studied, also preparations obtained by crushing the isolated vesicles of the fruit pulp under a cover-glass.

1. *The Epicarp Cells* (*Ep*) are rather thick-walled, sharply polygonal, and from 10–25 μ in diameter. Division of the mother cells into daughter cells is often evident. Beautifully formed stomata nearly circular in outline occur in considerable numbers; the epidermal cells about each stoma being more or less concentrically arranged. The color of the

orange rind is due to chromatophores present not only in the epidermis but in the subepidermal layers and also in the vesicles of the pulp.

2. *Hypoderm.* This tissue consists of rather small collenchyma cells in which ground tissue are the oil cavities (*scb*). These latter contain yellow drops of essential oil secreted by the delicate cells lining the cavity. In the cells of the ground tissue are numerous needle-shaped crystals of a glucoside, hesperidin (*He*), which, in alcoholic specimens, occur in dense spheroidal aggregates. Hesperidin is very abundant in the green fruit of all varieties, but diminishes in amount on ripening. The amount present at maturity in the sweet orange is, however, much greater than in the fruit of the bitter variety, a distinction of some value in the examination of marmalades. Cells here and there contain single monoclinic crystals of calcium oxalate (*kr*).

3. *Mesocarp* (Fig. 295). The close tissue of the hypoderm passes by degrees into a colorless spongy parenchyma which makes up the white

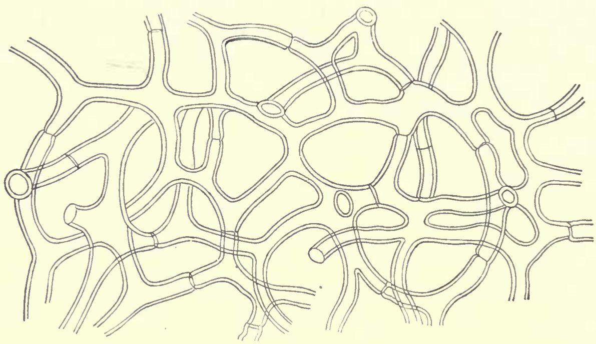


FIG. 295. Orange. Spongy parenchyma from inner layers of peel. (BERG.)

tissue forming the larger part of the rind and the middle layers of the partition walls through which the segments separate. Owing to the large intercellular spaces and the narrow arms of the cells, this tissue presents a striking appearance in tangential section, and is also noticeable in the débris found in marmalades.

4. *Endocarp.* The membranous skin or endocarp inclosing the segments consists of greatly elongated, narrow cells transversely arranged. These are for the most part thin-walled, but individuals here and there have sclerenchymatized walls pierced by oblique pores, making the tissue especially noticeable in marmalades.

5. *Vesicles* (Fig. 296). Tschirch and Oesterle find that in the green fruit two forms of multicellular hairs occur on that portion

of the endocarp adjoining the rind; one, club-shaped with smooth surface, the other more or less knob-shaped with glandular epidermal cells forming an aggregate resembling a bunch of grapes. The former develop into the fruit vesicles, while the latter remain small and are not noticeable in the mature fruit. The vesicles are thread-like at the base, broadening into the distended and elongated bodies containing the fruit juice. The outer layer of these consists of narrow, fiber-like cells, the walls of which, although usually thin, occasionally are thickened like the sclerenchyma cells of the endocarp. In the inner portion of the vesicle the cells are

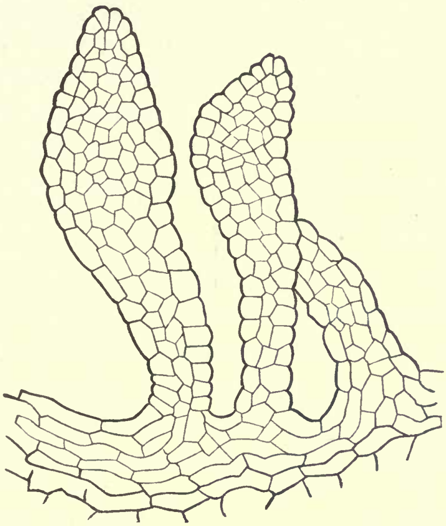


FIG. 296. Orange. Multicellular hairs from inner surface of pericarp of an unripe fruit. These develop later into the fruit vesicles. (TSCHIRCH.)

larger and more isodiametric in form. The yellow color is due to chromatophores.

The Spermoderm may be studied in cross sections of the entire seed, also in preparations obtained by stripping off the outer and inner layers.

1. *Outer Epidermis.* The sclerenchyma cells are 12–20 μ broad, 350–400 μ long, and 100–225 μ high, the latter dimension not including the mucilaginous outer walls which often swell to a thickness of over 150 μ, forming a structureless hyaline layer about the seed. Being elongated both longitudinally and radially, in surface view they appear like fibers, in cross section like palisade cells. The outer ends of the sclerenchymatized portions are of various curious shapes, appearing in cross section

like beaks projecting into the outer mucilaginous layer. The walls are narrower than the cavity and are distinctly porous.

2. *The Middle Spermoderm* forms a close tissue in the layers adjoining the epidermis, passing into a spongy parenchyma further inward.

3. *Inner Epidermis.* The cells are elongated and contain a brown substance.

Perisperm. Several layers of rather thick-walled cells form a tissue resembling the aleurone cells of various oil seeds.

The Endosperm is either not evident at all or only as an obliterated structureless membrane.

Embryo. According to Tschirch and Oesterle, only one of the several embryos is a product of the embryo sac, the others being formed in the outer layers of the nucellus at the end of the ovule without special fertilization. The nucellar embryos are none of them so well developed as the one formed in the embryo sac, only two at the most being capable of sprouting. The cells contain rounded aleurone grains from 2–10 μ in diameter, with numerous globoids.

DIAGNOSIS.

Orange Marmalade usually contains slices of the rind. Under the microscope we note the sharply polygonal epidermal cells, also the cells of the hypoderm containing numerous orange-colored chromatophores. Needle-shaped crystals of hesperidin are often found distributed in the outer rind, especially if the marmalade was made from the common or sweet orange. After soaking for some time in alcohol they are evident as spherical aggregates as well as isolated raphides. The oil cavities (Fig. 294, *scb*) are macroscopic objects.

The spongy parenchyma (Fig. 295) of the inner mesocarp, characterized by the narrow arms of the cells and the large intercellular spaces, is easily found in the débris, notwithstanding the thinness of the walls and the absence of color.

Other characteristic elements are the fiber-like cells of the endocarp, some of which are sclerenchymatized, and the elongated epidermal cells of the vesicles, united into a thread at the base.

Orange seeds are occasionally found in marmalades. Their shape, the presence of more than one embryo and other macroscopic characters usually suffice for their identification. Under the microscope the sclerenchymatized epidermal cells, both radially and longitudinally elongated, are the most conspicuous features. In cross section the outer beak-like extremities extending into the swollen, apparently structureless, mucilaginous layer, identify them beyond doubt as seeds of a citrus fruit.

An examination of orange marmalade should include a search under the microscope for the pulp of cheaper fruits and vegetables. All the common citrus fruits have practically the same structure. Adulteration of one with the other is improbable.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Blyth (5); Hanausek, T. F. (16); Hassall (19); Planchon et Collin (34); Tschirch u. Oesterle (40).

MOELLER, H. J.: Unterscheidung von Cortex Aurantii fructus und Apfelsinenschalen. Arch. Ph. og. Ch. **28**, 369.

STRASBURGER: Das Botanisches Practicum.

LEMON.

The lemon (*Citrus medica* L. var. *Limon* L.) differs from the orange in color, shape, and flavor, but not in microscopic structure. The seed seldom contains over three embryos and often only one.

BIBLIOGRAPHY.

BIERMANN: Beiträge zur Kenntniss der Entwickelungsgeschichte von *Citrus vulgaris* Risso und anderen Citrus-Arten. Arch. d. Pharm. 1897, **235**, 19.

ROSS: On the structure and development of the lemon. Bot. Gazette, 1890, **15**, 262.

CITRON.

The citron (*Citrus medica* L. var. *genuina* Engler) is much larger than the lemon, being often 15–18 cm. long and 8–10 cm. broad. The thick rind of the green fruit (2–4 cm.) is candied for use in cakes and confections.

In cross section the cells are nearly circular, forming a loose parenchyma tissue with oil cavities near the outer surface. The epidermal cells are the same as those of the orange and lemon.

Possible substitutes are the rind of the water-melon and other cucurbits.

MISCELLANEOUS FRUITS.

GRAPE.

The Old World grape (*Vitis vinifera* L. order *Vitaceæ*), a native of the East, has been cultivated since time immemorial in Europe, and within the past half century has been successfully introduced into California.

There are innumerable varieties differing in size, shape, and color of the berries, as well as in their flavor, acidity, and wine value. Aside from their use for wine production, the fresh berries are among the most delicious of table fruits and the dried berries or raisins are everywhere common sweetmeats.

Xanti currants are the dried seedless berries of a grape (*V. vinifera* var. *apyrena* L.) grown in the Ionian Islands and neighboring regions.

Excepting those raised in the Pacific States, American grapes are largely derivatives of *V. Labrusca* L., *V. æstivalis* Michx., *V. rotundifolia* Michx., and other native species, although some are hybrids with *V. vinifera*. The northern fox grape (*V. Labrusca*) is the parent of the Concord, Hartford, and others of the most valuable varieties. Berries of the American varieties are more valuable as table fruit and for preserves than for wine-making.

The morphology of both the fruit and the tissues is practically the same in all the European and American grapes, excepting the Xanti currant and other seedless varieties. The berry has a smooth epicarp (often with a bloom), a pulpy mesocarp, but lacks a conspicuous endocarp. Each of the two locules normally contains two seeds, but often only one, or in the case of the Xanti currants, none at all. The seeds (Fig. 297, *A*) are pear-shaped, 5–8 mm. long. On the ventral side are two longitudinal grooves penetrating into the tissues of the endosperm. Between these runs the raphe, extending from the hilum at the narrow end of the seed over the apex or broad end to the chalaza situated on the dorsal side near the apex, its position being marked by an oval depression. The reserve material is largely in the form of horny endosperm. In cross section, owing to the grooves on the ventral side, the endosperm is mushroom-shaped. The minute embryo situated in the narrow end of the seed may be isolated after soaking for some days in 1¼ per cent. alkali.

HISTOLOGY.

The Pericarp of the grape lacks throughout characteristic tissues, thus facilitating the identification of foreign matter with marked characteristics. Sections are easiest prepared from fully formed but not fully mellowed berries, hardened in alcohol.

1. *Epicarp.* The cells are polygonal, 15–40 μ in diameter, without any characteristic features. Cross sections show that the outer wall is about 7 μ thick with a roughened cuticle.

2. *The Hypoderm Cells* are tabular and increase in size from without inward, passing finally into the pulp cells of the mesocarp.

3. *The Mesocarp* or fruit flesh consists of thin-walled pulp cells and fibro-vascular bundles. Howard notes that needle-shaped crystals are present, also crystal fibers attached to the bundles. The vascular elements of most of the bundles are entirely spiral vessels, but the larger bundles, particularly of the European grape, often contain in addition pitted elements.

4. *Endocarp.* There is no sharply differentiated endocarp, the cells being thin-walled with the same general characters as those of the mesocarp.

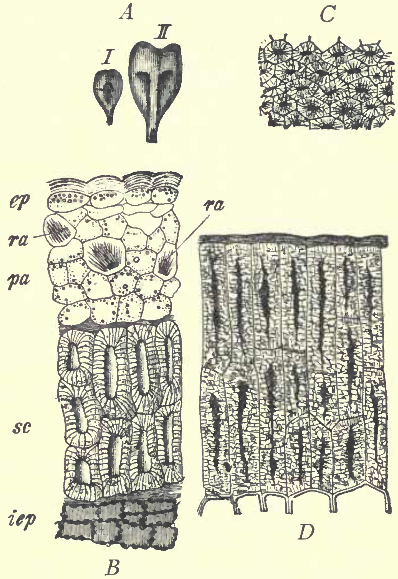


Fig. 297. Grape (*Vitis vinifera*). *A*, *I* seed, ventral side with chalaza, natural size; *II* dorsal side with hilum, ×2. *B* cross section of spermoderm showing *ep* outer epidermis, *pa* parenchyma with *ra* raphides, *sc* sclerenchyma layer and *iep* inner epidermis. *C*, *D*, sclerenchyma layer of Malaga grape in surface view and cross section. (T. F. Hanausek.)

Spermoderm (Fig. 297). Seeds of any variety of European or American grape or of raisins may be studied, as observations indicate that all are the same in structure. Surface mounts are prepared of the outer and inner spermoderm and cross-sections of the entire seed. The latter should be bleached with Javelle water and stained with safranin to bring out the inner layers of the spermoderm.

1. *Outer Epidermis* (*B*, *ep*). Seen in surface view, the somewhat elongated cells are from 20–60 μ broad, and have thin colorless walls. Cross sections show that the outer wall is thickened and cuticularized.

2. *A Parenchyma* (*B*, *pa*) of thin-walled cells forms a subepidermal coat, which over most of the surface is from 2–6 cell-layers thick, but in the grooves is thicker. Many of the cells contain bundles of beautifully formed raphides, evident both in cross sections and in surface mounts. The inner layers are often colored brown.

3. *Stone-cell Layer* (*B*, *se*; *C*; *D*). This exceedingly hard coat makes up by far the greater part of the spermoderm. It varies in thickness from less than 75 μ to over 500 μ. In the grooves it bends sharply and extends much deeper into the endosperm than does the parenchyma. Here, however, the layer is thin, often less than 75 μ, whereas the parenchyma over it is thicker than in other parts of the seed. At first sight the dense brown tissue appears to consist of a single layer of enormously elongated radially arranged cells forming a palisade layer, but on careful examination it is clear that only in the thinner portions is there but a single layer, the thicker portions consisting of an aggregate of moderately elongated or even isodiametric stone cells arranged end to end in radial rows. All of these cells have strongly thickened walls and narrow cavities.

4. *Lattice Cells.* This cell-layer is obtained with some difficulty by cutting open the seed, picking out the endosperm, and scraping the inner surface of the spermoderm with a scalpel. The cells are for the most part longitudinally elongated, exceedingly narrow (6–10 μ), and have numerous small but very distinct spiral reticulations, giving them a latticed appearance. In cross section the layer appears like a thin brown line of a darker color than either the stone cells or the inner epidermis, but on bleaching with Javelle water and staining, the reticulations are evident.

5. *Inner Epidermis.* Quite as remarkable as the lattice cells and much easier to find, are the cells of this layer. They are polygonal, 12–35 μ in diameter, and have yellow, porous radial walls, which in surface view are 4–5 μ broad and very distinctly beaded.

Perisperm. A hyaline band of obliterated cells is evident in cross section.

Endosperm. The cells are rather small, seldom exceeding 40 μ, and have moderately thick but distinct walls. Sections mounted in turpentine serve for the study of the remarkable aleurone grains which have been described by Tschirch, Lüdtke, and others. The large, irregularly spherical, solitary grains reach 25 μ in diameter, and inclose either an oxalate rosette 5–10 μ in diameter, or a large globoid. The numerous small grains are 3–6 μ in diameter.

The Embryo is so minute and so encased in hard tissue that it is difficult to study. It has no characters of diagnostic importance.

DIAGNOSIS.

Grape Preserves contain either the whole fruit or only the skin and fruit flesh, both of which lack distinctive characters. The epidermal cells are polygonal, resembling those of the currant, plum, and many other products, and the pulp cells are not characteristic. Most of the vascular elements of the bundle are spiral vessels. Calcium oxalate raphides occur in greater or less abundance.

The seeds (Fig. 297, *A*) are recognized by their pear-shaped form, the two grooves on the ventral side and the hilum depression on the dorsal side near the apex. Cross sections of the endosperm are mushroom-shaped. The characteristic tissues of the spermoderm (*B*) include the crystal-bearing parenchyma, the brown stone cells, the lattice cells, and the yellow, beaded inner epidermis. The solitary aleurone grains of the endosperm and the oxalate rosettes and globoids are also worthy of notice, the rosettes appearing most distinct after the proteid matter has been dissolved in dilute alkali.

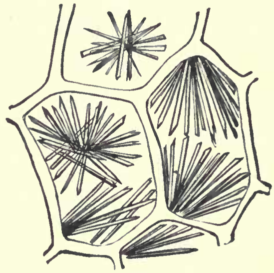


FIG. 298. Raisin. Section of fruit flesh showing crystals of sugar. (VOGL.)

Raisins are used in cakes, sweetmeats, etc., either whole or chopped, with or without the seeds. The cellular elements are the same as have been noted under preserves. Sugar crystals (Fig. 298) often separate in the cells, and are seen after mounting in alcohol or some other medium in which they are not soluble.

Xanti Currants contain the same elements as the grape and raisin, except that they lack fully developed seeds. Brown abortive seeds are always present.

Grape Pomace and other refuse from the wine-presses have been utilized in various ways, both as food for the lower animals and as adulterants.

Ground Grape Seeds serve as adulterants of coffee and possibly of other products. They are easily identified by the characters already noted.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Hanausek, T. F. (10, 16); Villiers et Collin (42); Vogl (45).

HOWARD: Microscopical Examinations of Fruits and Fruit Products, U. S. Dept. Agr., Bur. Chem., Bull. 66, 103.

LAMPE: Zur Kenntniss des Baues und der Entwickelung saftiger Früchte. Ztschr. Naturw. 1886, 59, 295.

SCHULER: Studien über den Bau und die Zusammensetzung der Traubenbeere. Die Weinlaube, 1880, 34.

FIG.

According to De Candolle, the fig tree (*Ficus Carica* L. order *Artocarpeæ*) grew wild in prehistoric times in a subtropical belt extending from Syria on the east to the Canaries on the west. It was cultivated in very early times in Egypt, Palestine, Greece, and Rome, and at later periods was introduced into France, Spain, Persia, India, and finally, in the eighth century, into China. Its culture in America dates from Colonial times, and is now an important industry in California and some of the southern states.

The numerous minute flowers are borne on the inner surface of a fleshy pear-shaped receptacle, communication with the outer air being through an opening or eye in the broad end. They are of four kinds: 1. Staminate flowers with five-parted perianth and four stamens, produced in considerable numbers only in the wild fig (caprifig, goat fig, Latin, *caprificus*). 2. Fertile pistillate flowers, also known as seed flowers, with three- to five-parted perianth and a long style. The inflorescence of the Smyrna fig and other cultivated sorts is largely or entirely of these flowers, caprification (fertilization) being effected only by the pollen of the wild fig, which is carried to the fertile flowers by a wasp breeding in the latter variety, hence the time-honored practice of tying a flowering branch of a caprifig to the cultivated tree during the flowering season. 3. Gall flowers, that is abortive pistillate flowers which do not develop seeds, but serve as a breeding place for the wasp, are instrumental in effecting caprification. They are found chiefly in the wild fig, and have short styles of such a length that the wasp is able to introduce its eggs into the ovary by means of its ovipositor. 4. Abortive flowers useless alike for the reproduction of the fig or of the wasp. In English they are known as mule flowers, and are the only ones present in numerous varieties, without perfect seeds.

Two or even three crops of figs are produced by some varieties. The first crop ("*Fichigrossi*," "*fiori*," or "*orni*" figs) is borne early in the spring on the old wood. Later in the season "*forniti*" figs are produced in the axils of the leaves on the lower portions of the new shoots, and "*cratiri*" figs on the upper portion.

The ripe fig is not a true fruit but an aggregate of small fruits or drupelets in a fleshy receptacle. In this respect it is like a strawberry, but the fruitlets are borne on slender stems over the inner surface, not sessile in depressions over the outer surface of the receptacle. The numerous yellow, pear-shaped "seeds," about 2 mm. long, found in ripe figs, whether fresh or dried, are the seeds proper invested by the hard inner pericarp The fruit, strictly speaking, is a drupe.

HISTOLOGY.

If fresh figs are not obtainable, the preserved fruit or even dried figs, soaked up in water, will answer for laboratory work.

Receptacle. The fleshy receptacle forms the larger part of the fig.

1. *The Epidermal Cells* (Fig. 299) are small, usually less than 20 μ in diameter, and have thick walls. Here and there they form rosettes, in the center of which are stout hairs (*h*) with globular bases up to 20 μ in diameter. Usually the hairs are short, sometimes scarcely twice as long as broad, but occasionally they reach a length of 300 μ. In the dried fruit they are often detached, although the scars with rosettes of cells about them are always evident.

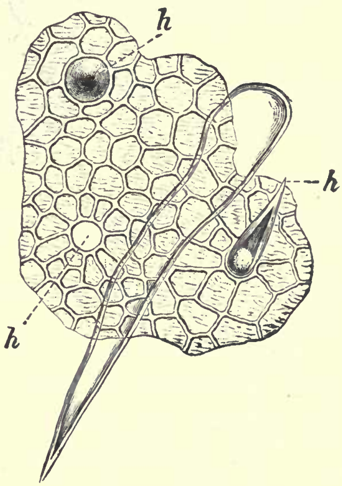


FIG. 299. Fig (*Ficus Carica*). Epicarp in surface view. *h* hairs and hair scars. ×160. (MOELLER.)

2. *Hypoderm.* Several layers of small cells with thick walls underlie the epidermis. They contain rosettes of calcium oxalate.

3. *Fruit Flesh* (Fig. 300). Proceeding inward, the cells increase in size but diminish in wall thickness, the bulk of the tissues consisting of loosely arranged, irregular cells usually about 100 μ in diameter. Their contents is largely sugar, which in the dried fruit is in crystalline form. Branching and anastomosing latex cells (*m*) ramify in great numbers through the outer layers of the fruit flesh, also sparingly through the inner layers. They are remarkable not only for their numbers but their size, reaching 50 μ in breadth. The walls are delicate but distinct. Numerous minute granules which are colored intensely yellow by iodine

solution are suspended in the milky contents. On warming, the latex coagulates, forming large drops. The fibro-vascular bundles occurring in the middle layer have small spiral or reticulated vessels usually only 15 μ broad, seldom over 25 μ.

4. *The Inner Epidermis* is of delicate-walled cells, which are not

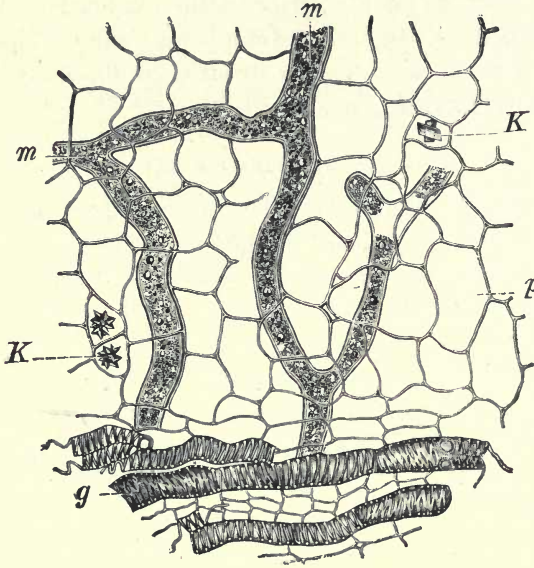


FIG. 300. Fig. Longitudinal section of fruit flesh showing *p* parenchyma, *K* crystals, *m* latex tubes and *g* vessels. ×160. (MOELLER.)

easily found in the ripe fruit. Hairs occur on this as well as on the outer epidermis.

Pericarp (Fig. 301). The inner surface of the receptacle is thickly beset with fruitlets inclosed by the perianth and borne on delicate stems. The perianth and stems are of thin-walled tissue of no special interest.

1. *The Epicarp Cells* are thin-walled, more or less radially elongated.

2. *The Mesocarp* of two or more layers is also of thin-walled, inconspicuous elements. Tschirch and Oesterle have shown that in removing the so-called seeds (inner pericarp and seeds proper) the tissues separate through this layer, part of the cells adhering to the outer layers, part to the inner.

3. *Outer Sclerenchyma* (*sc*). This consists of exceedingly small stone cells 15 μ in diameter in a single layer.

4. *The Endocarp* (*st*) or inner sclerenchyma is composed of one or more layers of rounded angular stone cells about 50 μ in diameter. The

have narrow lumen and thick walls with distinct rings and numerous branching pores. They are readily distinguished from the smaller cells of the outer sclerenchyma.

Spermoderm (Fig. 302). The seed, which as a rule does not completely fill the locule, is enveloped by a brown spermoderm, consisting of two or more layers of thin-walled, polygonal, isodiametric or somewhat elongated, often compressed cells (*a*, *i*).

The Endosperm (Fig. 302, *E*) makes up about half the bulk of the

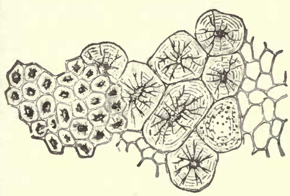


FIG. 301. Fig. Elements of pericarp (shell of nutlet) in surface view. *sc* outer sclerenchyma layer; *st* stone cells of endocarp. ×160. (MOELLER.)

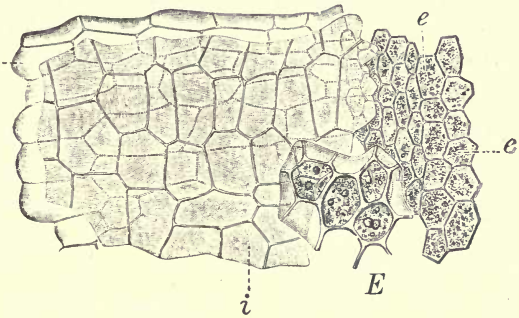


FIG. 302. Fig. Elements of seed in surface view. Spermoderm consists of *a* colorless outer epidermis and *i* brown inner layers; *E* endosperm; *e* embryo. ×160. (MOELLER.)

seed. The cells are thick-walled, polygonal, about 50 μ in diameter, and contain proteid matter and fat.

The Embryo (Fig. 302, *e*) is curved so that cotyledons and radicle almost meet. Small thin-walled cells without marked characters make up the tissues.

DIAGNOSIS.

Preserves. Whole figs preserved in syrup or cordial are easily identified by their form, taste and the numerous "seeds." If, however, they are cooked to a pulp the microscope should be brought into service. As the fig is one of the cheapest fruits in southern Europe, it, like the apple in America, is used as an adulterant of preserves purporting to be made from more valuable fruits. Marpmann has found tissues and seeds of the fig in numerous samples of strawberry, raspberry, and currant preserves.

Fig Coffee, consisting of the dried, roasted, and ground figs, is a popular coffee substitute in various parts of Europe. It is adulterated with cereal products, legumes, chicory, and even, so it is stated, with foreign seeds; on the other hand, it may itself serve as an adulterant of genuine coffee.

The microscopic identification of figs, whether in preserves or fig coffee, requires a knowledge of the tissues of both the receptacle and seed. The important elements are the outer epidermis of the receptacle with hairs (Fig. 299), the oxalate crystals of the hypoderm, the latex tubes (Fig. 300, *m*), often 30–50 μ broad (in chicory usually less than 10 μ), and finally the "seeds" (drupelets). The macroscopic appearance of the latter, also the peculiar manner in which they crush between the teeth, usually suffices for their identification, but in doubtful cases should be supplemented by an examination of surface preparations (Figs. 301 and 302) and cross sections. The strawberry and fig nutlets are remarkably similar in macroscopic appearance, and a careful microscopic examination may be necessary in some cases to distinguish them. The crystal layer of the pericarp and the reticulated epidermis of the spermoderm are characteristic tissues of the strawberry nutlet, with no counterparts in the fig.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Hanausek, T. F. (10, 16); Macé (26); Moeller (29); Planchon et Collin (34); Schimper (37); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (43, 45).

MARPMANN: Beiträge zur mikroskopischen Untersuchung der Fruchtmarmeladen. Ztschr. angew. Mikr. 1896, **2**, 97.

NEVINNY: Zur Verfälschung des Feigenkaffees. Ztschr. Nahr.-Unters. Hyg. 1887, **1**, 85.

DATE.

The date palm (*Phœnix dactylifera* L. order *Palmæ*) flourished in the gardens of the East long before the Christian era. At the present time it is cultivated in all the countries bordering on the Mediterranean, particularly in North Africa and Palestine, and also in Arabia and Persia, the fruit being the chief article of diet in many regions. The Arabs of the desert depend on this tree for both food and shelter, and regard it with special veneration.

Dates are of many varieties, differing in size (4–8 cm.), form, and color.

The mesocarp is about 1 cm. thick and contains a high percentage of sugar. A hard endocarp like that of the cocoanut and oil palm is lacking; on the other hand, the seed (2–3 cm. long and 0.5 cm. broad) consists almost entirely of hard endosperm resembling that of the ivory-nut. On the dorsal side of the seed midway between the two ends, a rounded cavity contains the minute germ, while a groove extends the entire length of the ventral side. The spermoderm forms a thin brownish coat about the seed or stone.

HISTOLOGY.

Pericarp. Lacking fresh or alcoholic specimens, the dried dates of commerce may be soaked in water and finally hardened in alcohol. As noted by Braun, cross sections show five layers.

1. *The Epidermal Cells* are of isodiametric form (10–30 μ) and colorless.

2. *The Hypoderm* consists of two or more layers of cells (20–50 μ), with yellow or brown contents.

3. *Stone Cells*, mostly radially elongated, form a layer of variable thickness.

4. *The Mesocarp Cells*, proceeding from without inward, pass from tangentially elongated forms first into isodiametric and finally into radially elongated forms.

5. *An Endocarp* of colorless, longitudinally elongated, collapsed elements forms a white silky-fibrous coat readily separable from the stone.

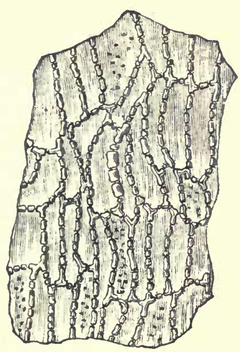


FIG. 303. Date (*Phœnix dactylifera*). Epidermis of spermoderm (outer layer of stone) in surface view. ×160. (MOELLER.)

Spermoderm. Stones from dried dates are easily cut with a strong razor.

1. *The Epidermis* (Fig. 303) is a single layer of narrow, elongated porous sclerenchyma elements, ranging in length up to 100 μ or more. On the middle of the dorsal side their longer diameters run parallel with the axis of the stone, but in other parts they are often transversely or diagonally arranged. They also occur side by side in groups, recalling the endocarp of the currant.

2. *The Middle Layer* (Fig. 304, *g*). All the cells are tangentially elongated. Directly under the epidermis, thick-walled porous elements occur here and there, but in the remaining two or more layers the cells are thin-walled, with side walls in interrupted contact, resembling the tube cells of cereals. These tube cells are often 20–30 μ wide and have brown contents. As a rule the outermost cells are extended in the same

direction as the epidermal cells; those in the inner layer however are often at an angle.

3. *Inner Layers.* One or two layers adjoining the endosperm are distinguished from the remainder, both in cross section and surface view, by their smaller dimensions and darker color.

Endosperm (Fig. 305). The reserve material of the stone is largely in the form of thickened cell-wall, the structure of which closely resembles that of the ivory-nut. Although varying greatly in thickness, the double walls are, on the average, 15 μ and seldom exceed 30 μ. Conspicuous pores, broadest towards the middle lamella, add to the striking appearance of these cells. In the outer layers they are radially elongated, in the heart, isodiametric. Oil is the only visible cell-contents.

DIAGNOSIS.

The Fruit Flesh enters into many pastries, sweetmeats, and candies. The epidermis, hypoderm, and stone cells are readily found, but are not very characteristic.

Date Stones are ground as a substitute or adulterant for coffee. Although both seeds have reserve material largely in the form of cellulose,

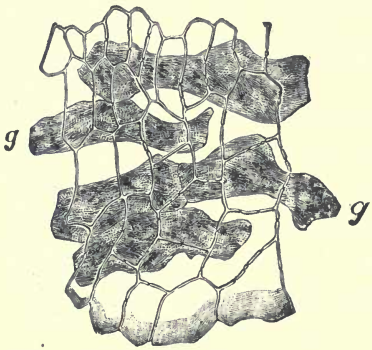


FIG. 304. Date Stone. Parenchyma of spermoderm and *g* tube cells in surface view. ×160. (MOELLER.)

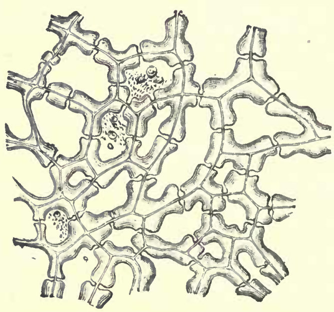


FIG. 305. Date Stone. Endosperm with thickened cell walls. ×160. (MOELLER.)

it is needless to say that date stones lack the valuable constituents of coffee.

Sections should be cut for the identification of this material. The thick walls (Fig. 305) with distinct pores are readily distinguished from the knotty thickened walls of coffee. The double walls seldom or never exceed 30 μ in thickness, whereas in the ivory-nut they average 35 μ. Tissues of the spermoderm (Figs. 303 and 304) are radically unlike any in coffee, and quite different from those of the ivory-nut.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Hanausek, T. F. (10, 16); Macé (26); Moeller (29); Planchon et Collin (34); Villiers et Collin (42); Vogl (45).

BRAUN: Ueber das Vorkommen von Sphärokrystallen aus Traubenzucker in den verschiedenen Drogen. Ztschr. allg. österr. Apoth.-Ver. 1878, **16**, 337.

HANAUSEK, T. F.: Ueber die Anatomie der Dattelkerne. Chem. Ztg. 1886, **10**, 701.

SACHS: Zur Keimungsgeschichte der Dattel. Bot. Zeit. 1862.

ZABUCKIE: Notes on the Structure of the Fruit Stone of the Date; *Phœnix dactylifera* L. Jour. N. Y. Micr. Soc. 1892, 8, 107.

BANANA.

The banana tree (*Musa sapientum* L. order *Musaceæ*) is a native of the Old World, but is very extensively cultivated in tropical America. It is said to produce more food in a given area than any other plant. Throughout the tropics the banana is a staple article of diet in many regions, being of more importance than all other foods taken together. It is eaten either raw or cooked. Bunches of bananas are also shipped green in enormous quantities to Europe and the United States, where they are ripened in well-ventilated lofts.

The elongated berry is either red or yellow, more or less angular, and varies in length from less than 10 to over 20 cm. It separates readily into a tough rind and a pulpy fruit flesh turning brown on exposure, the latter showing in cross section three indistinct locules with minute brown abortive seeds. The plantain (*M. sapientum* var. *paradisiaca* Hort.) has a larger fruit, which, like some varieties of the banana, is picked green and eaten cooked.

HISTOLOGY.

A green banana will be found much easier to section than one fully ripe. Transverse, longitudinal, and tangential sections should be prepared, also mounts of the isolated fibers and abortive seeds.

Pericarp. The rind, or so-called peel, containing most of the bundles, is easily stripped from the fruit pulp, the separation being through the delicate tissues of the outer mesocarp.

1. *The Epicarp Cells* are small, polygonal, and thick-walled. Tangential sections show an indistinctly striated cuticle.

2. *Hypoderm.* The remaining layers of the peel may be arbitrarily designated either hypoderm or outer mesocarp. The cells of the outer layers of ground tissue are small, rather thick-walled, and closely arranged; but proceeding inward, the cells increase in size, the walls decrease in thickness, and the arrangement becomes more loose and spongy. The numerous bundles running through this ground tissue consist in the outer layers entirely of bast fibers, in the inner layers of the usual fibro-vascular elements. Especially noticeable are the extraordinary size of the spiral vessels (often 50 μ in diameter) and their loosely wound spirals. Accompanying each bundle are one or more chains of very conspicuous brown-walled, rounded, giant cells about 250 μ broad, resembling the oil-ducts of umbelliferous seeds.

3. *Mesocarp.* The fruit flesh is a mass of rounded pulp cells which, in the outer layers, are nearly isodiametric, but in the inner layers are radially greatly elongated and readily separate as chains. Fibro-vascular bundles like those already described occur sparingly in the outer and also in the inner layers. The curiously shaped starch grains (Fig. 306) are much elongated, mostly 20–40 μ, occasionally 75 μ long, and

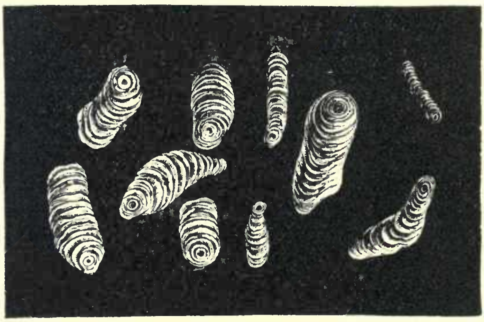


FIG. 306. Banana Starch. $\times 300$. (MOELLER.)

have an excentric hilum, mostly in the broader end, and very distinct rings. Among the grains are fusiform, cigar-shaped, ovoid, rod-shaped, and other striking forms. Tschirch and Oesterle lay particular stress on the "sickle-shaped" forms, consisting of two curved grains united end to end. The fleshy partitions contain numerous bundles accompanied by chains of brown giant cells like those in the hypoderm. E. Munroe Bailey has shown that the starch largely disappears during ripening

4. *Endocarp.* The inner layer of the pericarp is made up of thin-walled cells mostly radially elongated.

The Seeds are abortive, of a brown color, and lack distinctive elements.

DIAGNOSIS.

Banana Flour. The ground dried pulp of the green fruit consists largely of starch and cellular débris. Not only the starch grains (Fig. 306), but also the broad, loosely wound spiral vessels and the chains of giant cells are characteristic.

Guiana Arrowroot or Banana Starch is a commercial product of some importance. The starch grains are elongated, curiously shaped, and have distinct rings. The hilum is usually in the broader end, whereas in the somewhat similar grains of curcuma and yam the hilum is in the narrow end.

PINEAPPLE.

The pineapple, one of the most delicious of tropical fruits, is the product of a herbaceous, endogenous plant (*Ananassa sativa* Schult. f., order *Bromeliaceæ*), a native of the West Indies and other regions of the New World. Like oranges and bananas, pineapples are now shipped to cooler regions in large quantities, but in Europe have not entirely supplanted the greenhouse product, which is said to have a finer flavor.

The fruit consists of numerous fleshy berries, each with a single fleshy bract, united with an axis, forming a conical composite fruit shaped like a pine cone, hence the name pineapple. Surmounting the fruit is a tuft of sword-shaped saw-toothed leaves. The tapering, more or less appressed extremities of the bracts are toothed. The chartaceous, persistent perianth lobes form a close, dome-like structure covering a cavity in which are the remains of the styles and stamens.

R. H. Chittenden has found that the pineapple contains an enzyme, "bromelin," possessing in a remarkable degree the power of digesting proteid substances.

HISTOLOGY.

The edible part of the pineapple is the fruit flesh freed from the harsh outer envelope and also from the fibrous core. As, however, the removal of these parts is not always complete, a knowledge of their histology is desirable.

The Bracts consist of hard outer and inner layers, with softer tissues between.

1. *The Outer Epidermal Cells* are small with wavy outline. The secondary walls are greatly thickened except for a spherical cavity

scarcely one-third the diameter of the cell, which is entirely filled by a silicious body.

2. *Outer Hypoderm.* One or more layers of very thick, sclerenchymatized, porous-walled cells underlie the epidermis. Cross sections show that these cells are thicker than broad, and tangential sections, that they are somewhat elongated.

3. *Mesophyl.* The hypodermal cells pass into a thin-walled but porous mesophyl, which, in the fleshy portions, is the same as the fruit flesh.

4. *Inner Hypoderm.* Beneath the inner epidermis is a second layer of sclerenchyma elements.

5. *Inner Epidermis.* This characteristic layer is composed of thin-walled, nearly square cells with sharply zigzag outline. They resemble somewhat the outer epidermal cells, but lack the silicious contents.

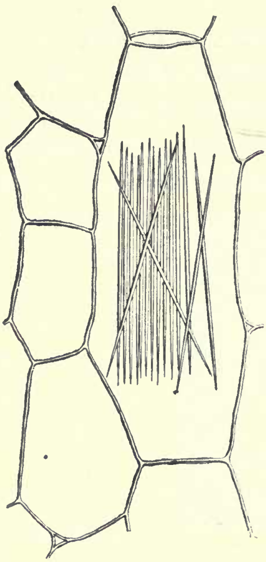


FIG. 307. Pineapple (*Ananassa sativa*). Cross section of fruit flesh showing raphides. ×160. (WINTON.)

Pericarp. No sharp distinction can be drawn between pericarp, perianth tube, and fleshy portion of bract, as they all unite to form the fruit flesh.

1. *An Epicarp* is present only in the disc surrounding the style. The cells are much like those of the hypoderm of the bracts, but are more distinctly porous and consequently in tangential section appear beautifully beaded.

2. *Mesocarp.* The cells of the fruit flesh are mostly isodiametric, and although thin-walled, are often distinctly porous. Beautiful raphides (Fig. 307), often over 100 μ long, occur in large numbers both singly and in bundles. The fibro-vascular bundles consist in large part of bast fibers with broad lumen and round pores, and broad spiral vessels often 25 μ in diameter.

3. *Endocarp.* The inner two or three layers are of tangentially elongated cells, those in the innermost layer, or endocarp proper, being very narrow, usually only 10–20 μ broad. The walls are thin throughout.

DIAGNOSIS.

In preserves the chief elements are the cells of the parenchymatous fruit flesh, containing large raphides (Fig. 307), and the fibro-vascular bundles, consisting chiefly of bast fibers with broad lumen and round pores, also large spiral vessels. Occasionally one finds fragments of the bracts and other outer parts, of which the characteristic elements are: first, the small, square epidermal cells with zigzag walls and, in the case of the outer epidermis, with silicious contents; and second, the thick-walled, somewhat elongated, sclerenchyma elements.

PART VII.

VEGETABLES.

VEGETABLES.

A number of the common vegetables are seeds and fruits picked while immature. The mature forms of some of these are described with the legumes (peas, bean, Lima bean), cereals (green corn), and spices (peppers) but identification of the vegetables by these descriptions is often difficult owing to the undeveloped condition of the tissues and starch grains.

The vegetables here described include most of the fruits used minced or pulped in commercial products, such as pickles and catsups; the common roots and tubers used for culinary purposes, cattle feeding, starch manufacture and adulterating food products; and certain edible fungi.

CUCURBIT FRUITS (*Cucurbitaceæ*).[1]

The fleshy mesocarp of these fruits contains curious branching latex tubes. Thin-walled stomata occur in great numbers on the epicarp. The numerous flattened seeds are borne within the three large locules on three double-central placentæ, but as these placentæ extend to the outer wall before branching, thus forming false partitions, the seeds appear to be borne on parietal placentæ.

Several characteristic tissues are found in the seed, of which the thin-walled, ribbed palisade cells of the epidermis (Figs. 309 and 310, *ep*) and the sclerenchyma cells of the third layer (*scl*) are much alike in all the important economic species.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Böhmer (6); Collin (8); Hanausek, T. F. (17); Harz (18); Planchon et Collin (34); Villiers et Collin (42).

BRAEMER: De la localisation des principes actifs des Cucurbitacées. Compt. rend. 1893, **117**, 753.

CARLES: Nouveau cas de fraude de conserves alimentaires. Journ. pharm. chim. 1885, **11**, 547.

[1] The descriptions of cucurbit fruits are by MISS KATE G. BARBER.

FICKEL: Anatomie u. Entwickelungsgesch. der Samenschalen einiger Cucurbitaceen. Bot. Ztg. 1876, **34**, 737.
FISCHER: Ueber das Siebrohren System der Cucurbitaceen. Leipzig, 1884.
GODFRIN: Étude histologique sur les tégument séminaux des Angiospermes. Soc. d. Sci. d. Nancy, 1880, 109.
HARTWICH: Semen Cucurbitæ. Arch. pharm. 1885.
v. HÖHNEL: Morpholog. Untersuchungungen über die Samenschale der Cucurbitaceen. Sitzungsber. Wiener Akad. 1876, **73**.
KOSUTANY: Die Kürbiskernkuchen. Landw. Vers.-Stat. 1893, **43**, 264.

PUMPKIN.

Wittmack, in his investigation of prehistoric remains in Peru, has secured evidence that the pumpkin (*Cucurbita Pepo* L.) is an American plant and not, as formerly believed, a native of the Old World. This belief is further substantiated by the statements of early explorers that the pumpkin was grown in maize fields by the aborigines just as is practiced to-day by American farmers.

The pumpkin is the largest of all cultivated fruits, in extreme cases reaching the prodigious weight of nearly 100 kilos. It is apple-shaped,

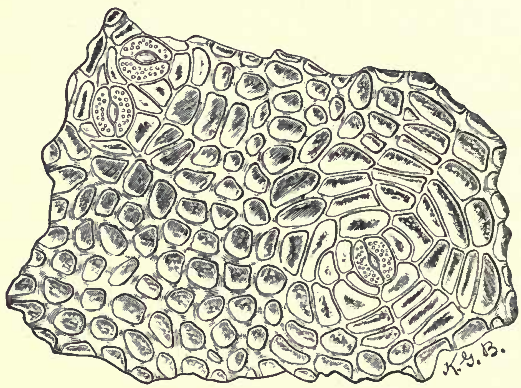


FIG. 308. Pumpkin (*Cucurbita Pepo*). Epicarp in surface view. ×300. (BARBER.)

smooth, and of an orange or green-orange color. The fleshy rind, consisting of receptacle and pericarp, is several centimeters thick, and is highly esteemed in America for making pies as well as for feeding. About the seeds is a tangle of gelatinous, mesocarp fibers, such as occur in the melon and some other cucurbitaceous plants. Pumpkin seeds are 1.5–2.5 cm. long, elliptical, strongly flattened, and have a narrow border on both sides. The embryo consists of two flattened cotyledons and a minute radicle.

HISTOLOGY.

Receptacle and Pericarp. 1. *The Epicarp Cells* (Fig. 308) are prismatic, forming a palisade layer upward of 50 μ thick. In surface view

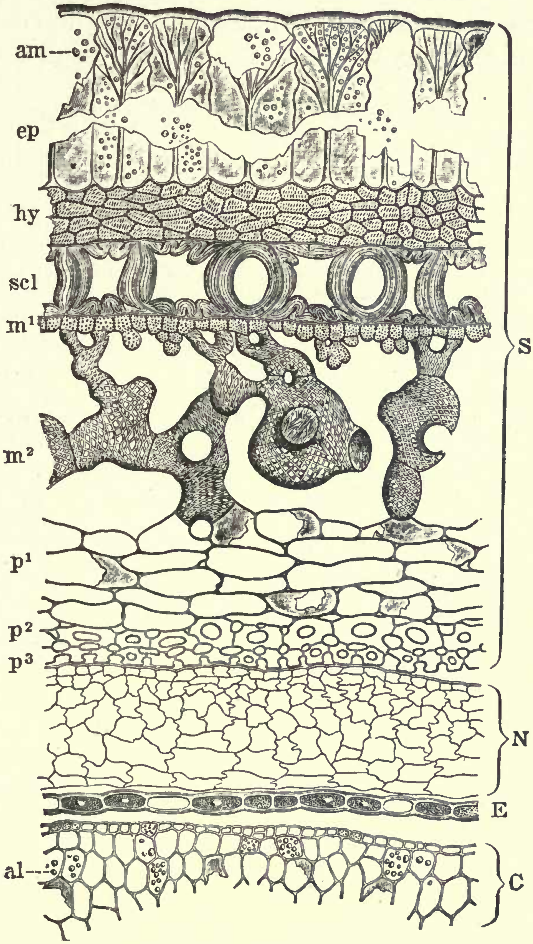


FIG. 309. Pumpkin. Seed in cross section. *S* spermoderm consists of *ep* ribbed palisade cells of epidermis containing *am* starch grains, *hy* pitted subepidermal cells, *scl* sclerenchyma layer, m^1 pitted mesocarp cells, m^2 reticulated spongy parenchyma, p^1 parenchyma, p^2 spongy parenchyma, and p^3 inner epidermis; *N* perisperm; *E* endosperm consisting of aleurone cells; *C* cotyledon containing *al* aleurone grains. $\times$160. (BARBER.)

they are for the most part polygonal and do not exceed 25 μ in diameter, but about the stomata they are somewhat elongated and curved. Their walls are bright yellow, whereas those of the stomata are colorless.

2. *Hypoderm.* Exceedingly small cells in several layers form the hypoderm.

3. *Mesocarp.* The noteworthy elements of the fruit flesh are the strongly developed spiral vessels of the fibro-vascular bundles, often 60 μ broad, some with single strands and turns wide apart, others with 2–4 strands and turns close together; also, accompanying the bundles, branching and anastomosing latex tubes. The ground tissue is of large, thin-walled, rounded elements.

4. *Endocarp.* This is evident on the seeds as a thin membrane.

Spermoderm (Figs. 309 and 310). Either fresh or dried seeds may

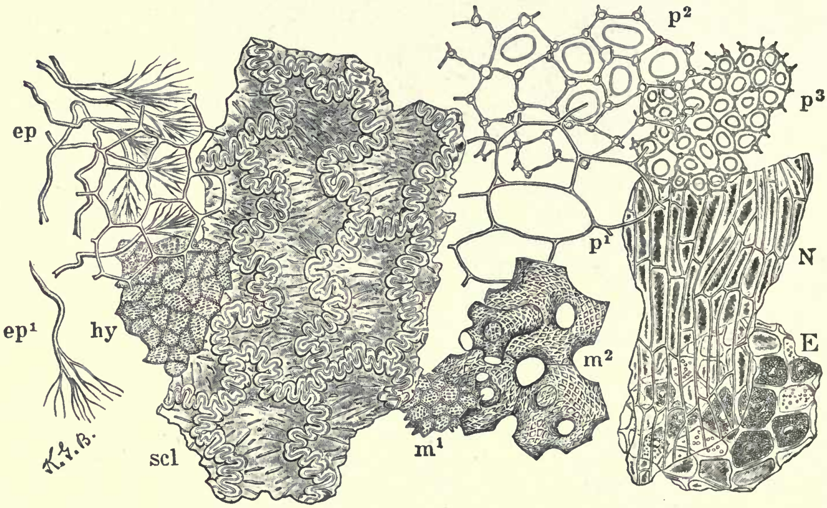


FIG. 310. Pumpkin. Seed elements in surface view. *ep* ribbed palisade cells of epidermis; *ep*¹ branching rib from epidermal cell; *hy* pitted subepidermal cells; *scl* sclerenchyma layer; *m*¹ pitted mesocarp cells; *m*² reticulated spongy parenchyma; *p*¹ parenchyma; *p*² spongy parenchyma; *p*³ inner epidermis of spermoderm; *N* perisperm; *E* endosperm. ×160. (BARBER.)

be used for making preparations, which should include transverse and tangential sections.

1. *The Palisade Epidermis* (*ep*) is remarkable not only for the great height of the cells (often over 200 μ), but also for the longitudinal ribs with branches at the outer ends which strengthen the radial walls. In cross section these might easily be mistaken for the walls themselves, but in tangential section they are seen to be circular rods on a thin cell-wall. These cells contain small starch grains (*am*).

2. *Pitted Subepidermal Cells* (*hy*). The small polygonal cells with numerous minute pores are arranged in 3–6 cell-layers.

3. *Sclerenchyma* (*scl*). Cross sections of the cells are often oval, showing thick walls pierced by numerous pores. In surface view the cells are elongated with wavy outline, and are arranged end to end in rows.

4. *Pitted Mesocarp Cells* (m^1). These resemble the cells of the sub-epidermal coat, but form only one distinct layer.

5. *Reticulated Spongy Parenchyma* (m^2). One or more layers of curiously reticulated cells with large intercellular spaces form the most remarkable tissue of the seed. Their appearance is alike striking in cross section and surface view and reminds one of a prickly pear cactus.

6. *Parenchyma* (p^1). The cells are large, of the usual type.

7. *Spongy Parenchyma* (p^2). The parenchyma passes by degrees into a remarkable spongy tissue with a large ring evident, in surface view, in the center of nearly every cell.

8. *The Inner Epidermis* (p^3). The cells resemble those of the proceeding layer but are smaller. The protuberance in the center of each cell forming the ring seen in surface view is evident in cross section.

Perisperm (*N*). This consists of a few layers of thin-walled cells more or less compressed.

Endosperm (*E*). A single layer of well-defined aleurone cells forms the endosperm.

Embryo (*C*). In sections examined in turpentine, we find numerous small aleurone grains 3–6 μ in diameter.

DIAGNOSIS.

Pumpkin Pulp is not only used for making pies, but also for adulterating tomato catsup, jams, and other fruit products.

The microscopic elements of the pulp of chief value in diagnosis, including the broad vessels, the latex tubes, and the epicarp (Fig. 308) with stomata, are largely although usually not entirely removed by straining.

Pumpkin-seed Cake is obtained in limited amount as a by-product in the manufacture of pumpkin-seed oil. The characteristic tissues of the spermoderm (Fig. 310) include the ribbed palisade epidermis (*ep*), the pitted parenchyma of the second layer (*hy*), the sclerenchyma cells with wavy outline (*scl*), and the reticulated spongy parenchyma (m^2).

SQUASH.

The fruit of numerous varieties of the winter squash (*Cucurbita maxima* Duch.) is put to the same uses as the pumpkin.

Squashes of the different varieties are widely different in macroscopic characters, and according to Harz are somewhat different in histological structure. In the main, however, their structure corresponds closely with that of the pumpkin.

CUCUMBER.

The cucumber or gherkin (*Cucumis sativus* L.) is a native of the East Indies, whence in ancient times its culture spread over various parts of Asia and Europe.

The succulent fruit picked green is prized not only as a fresh vegetable eaten either raw or cooked, but also for pickling.

Although variable in shape, it is usually elongated, in section rounded triangular, and has numerous warts on the surface, each capped by a short, blunt spine, which readily becomes detached on handling. The fleshy pericarp is green in the outer layers, but white further inward. Numerous flattened seeds are embedded in a gelatinous substance within the three locules. The cream-colored seeds are seldom over 2 mm. thick even when fully ripe, and are not, as in the case of the pumpkin seed, provided with a distinct border.

HISTOLOGY.

Cucumbers are often picked for pickling at such an early stage in their development that they do not show very marked differentiation of the tissues. When, however, they reach a diameter of 3 cm. or more, the structure both of the pericarp and seed is sufficiently characteristic to permit their identification with some degree of certainty.

Pericarp. The following description applies to the half-grown fruit:

1. *The Epicarp Cells* are prismatic with thin walls. They reach the height of 75 μ or more and vary from 7–20 μ in breadth. They do not contain chlorophyl grains.

2. *Hypoderm.* Several layers of small, rounded, loosely arranged cells containing numerous chlorophyl grains form the subepidermal tissues, to which the fruit owes its green color.

3. *The Mesocarp,* or more correctly the fruit flesh, is a colorless mass of loose parenchyma, through which run the fibro-vascular bundles.

The Spermoderm is best studied in seeds taken directly from a ripe cucumber, as those obtained from a seedsman often lack the outer epidermis.

1. *The Palisade Epidermis* is thickened by rods, which differ from those of the pumpkin in that they are sclerenchymatized and do not branch at the end.

2. *Pitted Cells.* These cells have thick porous walls and are arranged end to end in rows forming a single cell-layer. Numerous small intercellular spaces are evident in surface view.

3. *The Sclerenchyma* is practically the same as in the pumpkin. In surface view this layer is very striking even in green cucumbers, owing to the wavy, sclerenchymatized cell-walls. It reminds us of the epidermis of oat chaff, but of course only elongated cells are present.

Spongy Parenchyma. This layer is made up of star-shaped cells with thin walls.

The Perisperm, Endosperm, and **Embryo** lack distinctive features.

DIAGNOSIS.

Not only whole cucumbers but quite small pieces are recognized by the warts on the surface, the thin elliptical seeds, and other macroscopic characters.

The microscopic elements of value in diagnosis are the palisade epidermal layers of both the fruit and the seed, and the sclerenchyma layer of the seed.

MUSKMELON.

The muskmelon (*Cucumis Melo* L.) is a native of southern Asia and tropical Africa.

The hollow fruit is spherical or slightly elongated with 8–12 narrow longitudinal grooves. The surface is yellow-green with brown reticulations.

HISTOLOGY.

Pericarp (Fig. 311). 1. *Epicarp.* The cells are prismatic, very thick-walled with a thick cuticle. The reticulations are of cork tissues which break through the epicarp similar to lenticels. In the grooves the epidermal cells have thinner walls and are accompanied by stomata and multicellular hairs.

2. *Hypoderm.* Moderately thick-walled pitted cells form this layer.

3. *Mesocarp.* Bundles and latex tubes are scattered through a mass of loose parenchyma.

Spermoderm. 1. *The Palisade Epidermis* is strengthened by rods without evident branches.

2. *Pitted Cells* with thickened walls form several layers.

3. *Sclerenchyma.* The cells are large with thick sinuous walls, and resemble those of the cucumber.

4. *Spongy Parenchyma.* This consists of 4–5 layers of slightly

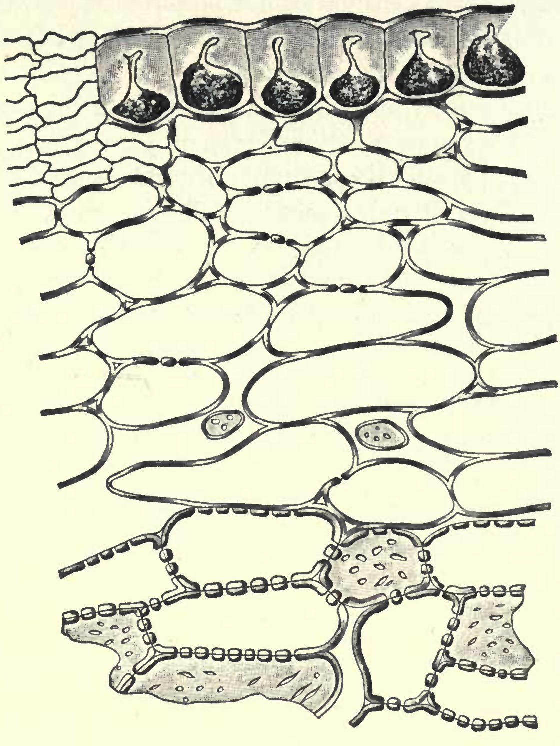


FIG. 311. Muskmelon (*Cucumis Melo*). Cross section of rind. (MOELLER.)

thickened porous cells intermediate in characters between the corresponding cells of the pumpkin and the cucumber.

Perisperm, Endosperm, and **Embryo** are like those of the cucumber.

WATERMELON.

The watermelon (*Citrullus vulgaris* Schrad.) comes to us from Africa, where it is eaten by the natives and the larger animals.

The large fruit is ellipsoidal with a dark-green surface, often mottled with light green. The rind or outer portion of the fruit flesh is white or light green, of firm texture; the inner portion is red, pink or yellow of looser texture, with numerous bundle fibers. Embedded in the inner pericarp are the black or light-brown, flat, lustrous seeds.

HISTOLOGY.

Pericarp. 1. *The Epicarp* consists of prismatic cells with thickened outer and radial walls.

2. *Hypoderm.* This is made up of 10–12 layers of indistinctly pitted cells.

3. *Stone Cells* in one or more layers form a distinct zone in the mature

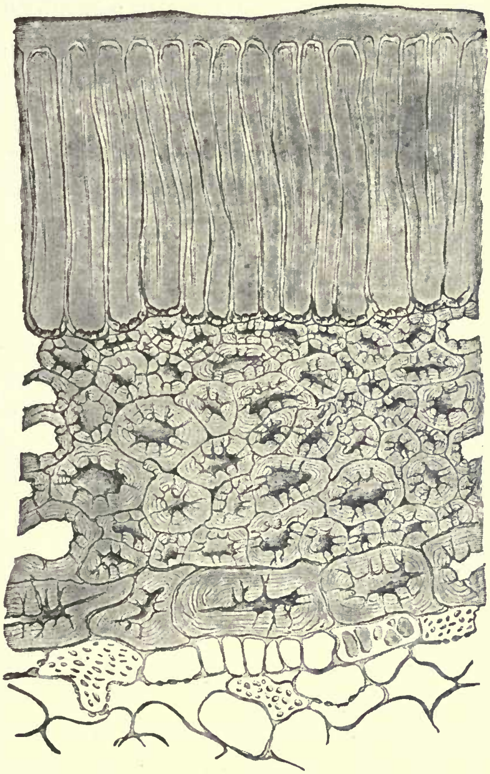


FIG. 312. Watermelon (*Citrullus vulgaris*). Cross section of outer layer of spermoderm showing the palisade epidermis, the sclerenchyma cells and the porous spongy parenchyma. (MOELLER.)

fruit. During the earlier stages of development these stone cells occur in groups, but later the groups become almost continuous.

4. *Mesocarp.* This tissue consists of parenchyma cells with moder-

ately thick, porous walls and intercellular spaces; among which ramify bundles and latex tubes.

Spermoderm (Fig. 312). The structure is much the same as in the cucumber, except that the rods of the palisade epidermis are smaller and more numerous, and the subepidermal stone cells form several layers with scarcely any intercellular spaces.

Perisperm, Endosperm, and **Embryo** are similar to the corresponding layers of the cucumber and the muskmelon.

SOLANACEOUS FRUITS (*Solanaceæ*).

This family yields a number of important products, of which the potato (p. 414) is a tuber, the eggplant and tomato are fleshy fruits, and the garden peppers are dry fruits. Cayenne pepper and paprika, the latter being but a variety of our garden peppers, are described under spices (p. 515). The structure of the tomato is of special interest because of the adulteration of tomato products.

TOMATO.

There is good evidence that the tomato (*Solanum Lycopersicum* L., *Lycopersicum esculentum* Mill.) was cultivated in Peru long before the discovery of America. A plant believed to be the original form of the species grows wild in Peru, also on the Pacific coast of Mexico and California. Numerous varieties are now grown as garden vegetables throughout the civilized world, except in the coldest regions.

The fleshy fruit varies in the different varieties from the size of a currant to the size of a cocoanut. Its color is red, pink, or yellow, according to the color of the fruit flesh; the smooth, lustrous skin, however, is bright yellow in all the varieties. Normally the fruit is bilocular, but as a result of cultivation is multilocular. Numerous seeds (Fig. 313) 3–4 mm. long, inclosed in a gelatinous mantle, partly fill the locules. Freed from this substance they are dull yellow, ovoid, flattened, 3–4 mm. long, and thickly beset with short, silky hairs. The spirally coiled embryo with elongated radicle and cotyledons, each about 3 mm. long, is embedded in the endosperm.

HISTOLOGY.

The ripe fruit should be hardened in alcohol before cutting sections. The skin is separated by plunging the fruit for a moment in boiling water. Soaking the seeds in a very dilute alkali facilitates the removal of the gelatinous material, after which they may be held between pieces of pith and sectioned.

Pericarp. The skin which separates from the fruit flesh consists of epidermis and hypoderm, the walls of both being characterized by their golden yellow color.

1. *Epicarp* (Fig. 314, *epi*). The cells, as seen in surface view, are polygonal, 16–35 μ in diameter. Their yellow radial walls are thick, 6–8 μ, and distinctly beaded. At the corners they are often collenchymatously thickened.

2. *The Hypoderm* (Fig. 314, *hy*) consists of a single layer of cells larger than those of the epicarp, but like the latter with thick, yellow, porous walls.

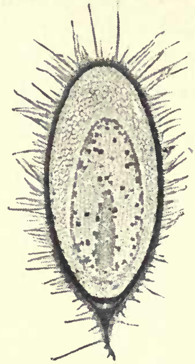


FIG. 313. Tomato (*Solanum Lycopersicum*). Seed in cross section. (MOELLER.)

3. *Mesocarp.* The rounded pulp cells of the ground tissue have no distinctive characters. The vascular elements of most of the bundles are spiral vessels, seldom over 20 μ in diameter, but those in the strongly developed bundles near the stem

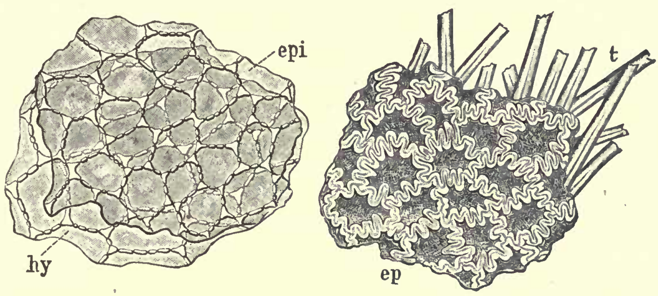


FIG. 314. Tomato. *epi* epicarp and *hy* hypoderm of pericarp (skin), ×300; *ep* outer epidermis of spermoderm with *t* hairs, from below. ×160. (WINTON.)

are partly pitted vessels. Bast fibers accompany these latter bundles but are lacking elsewhere.

4. *Endocarp.* This layer is of thin-walled, polygonal elements hardly distinguishable from the pulp cells.

Spermoderm (Fig. 314; Fig. 315, *S*). 1. *The Outer Epidermis* (*ep*) is highly characteristic owing to numerous peculiar hairs (*t*), varying up to over 500 μ in length. These hairs are broadly conical at the base, but taper gradually from this to the apex. The lumen in the basal portion is triangular, in the remainder of the hair very narrow or not evident at all. They remind one of funnels with long stems.

2. *The Middle Layers* consist of several layers of small, brown, obliterated cells, which in the ripe seed do not assume their original form even after treatment with reagents.

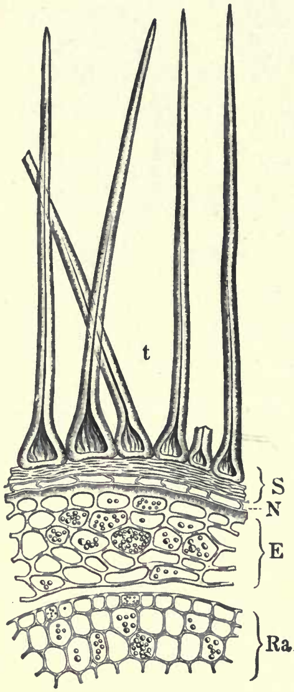


FIG. 315. Tomato. Seed in cross section. *S* spermoderm consists of *t* epidermal hairs, also layers of compressed cells; *N* perisperm; *E* endosperm and *Ra* radicle, both containing aleurone grains. ×160. (WINTON.)

The Perisperm (Fig. 315, *N*), after treatment of cross sections with Javelle water, is seen to consist of a distinct layer of thin-walled cells.

Endosperm (Fig. 315, *E*). The cells have rather thick, rigid walls. They contain minute, rounded aleurone grains seldom over 6 μ in diameter, and fat.

The Embryo consists of typical embryonic tissues with contents the same as those of the endosperm.

DIAGNOSIS.

Whole Tomato Products. Under this head are included canned tomatoes, tomato preserves, and other preparations of the whole fruit, from which the skin has been removed by scalding. The chief microscopic elements are rounded pulp cells, vascular elements (chiefly small spiral vessels) and seeds thickly beset with characteristic nail-shaped hairs (Figs. 314 and 315, *t*). Fragments of the skin with golden yellow porous cells of the epicarp (Fig. 314, *epi*) and hypoderm (*hy*) are frequently present in small amount as an accidental impurity, even in products made from the pared fruit. The adulterants are dyes, preservatives, foreign pulp and, in the case of preserves, agar-agar, starch-paste, and other gelatinous materials.

Tomato Catsup, or Ketchup, a popular sauce in the United States, is manufactured in enormous quantities, and sold in bottles. Properly made it consists of a mixture of tomato pulp, freed from seeds, with vinegar and spices; but most of the catsup on the market is colored with ponceau, eosin, or other coal-tar dyes, and preserved with sodium benzoate or salicylic acid. Adulteration with pumpkin pulp and possibly with the pulp of the carrot, turnip, and sugar beet is also practiced. The coal-tar dyes usually employed in tomato products do not remain in solution, but are taken up by the protoplasmic contents of the cells, which ordinarily have little or no color. Their detection is best effected by Arata's wool test [1] and other chemical methods. Preliminary to the usual chemical tests for salicilic and benzoic acids, Lagerheim's sublimination test (p. 321) should be employed.

For the detection of foreign pulps it is advisable to examine the coarser material, consisting of seeds, fragments of skin, and vascular elements, obtained by washing on a sieve with 1 mm. mesh in a stream of water. The vessels of the pumpkin are larger than those of the tomato; the epicarp cells (Fig. 308) are smaller, non-porous and are interspersed with stomata. Still more characteristic are the branched and jointed latex cells of the mesocarp. The carrot (Fig. 322) is characterized: (1) by the elongated epidermal cells; (2) by the polygonal cells of the cortical parenchyma containing chromoplasts; and (3) by the elements of the bundles, of which the rather large vessels (often 50 μ broad) with closely crowded reticulations, are quite different from the vessels of the tomato. The vessels of the beet (Fig. 321) are mostly 50 μ broad (sometimes 50–100 μ), with very large and open reticulations. A noteworthy peculiarity of the reticulated vessels of the turnip (Fig. 323), are their short joints, often broader than long. The meshes are smaller than those of beet vessels.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Macé (26); Villiers et Collin (42).

BRIOSI e GIGLI: Intorno alla struttura anatomica ed alla composizione chimica del frutto del Pomodoro (*Lycopersicum esculentum* Mill.). Rendic. delle sess. della R. Acad. delle scienze dell'Ist. di Bologna. 1889, 59.

CARLES: Nouveau cas de fraude de conserves alimentaires. Journ. pharm. chim. 1885, **11**, 547.

HOCKAUF: Ueber bisher wenig berücksichtige Merkmale der Solanaceen-Samen. Ph. Centralh. 1905.

MARPMANN: Beiträge zur mikroskopischen Untersuchung der Fruchtmarmeladen Ztschr. angew. Mikr., 1896, **2**, 97.

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[1] Ztschr. anal. chem. 1889, **28**, 639; Jour. Am. Chem. Soc. 1900, **22**, 582.

TUBERS AND ROOTS.[1]

Of the vegetables produced underground some are tubers (potato, artichoke), others, true roots (beet, carrot, turnip, sweet potato), and others still, bulbs (onion). Those here described include some that are used minced or pulped in food products.

The potato and the beet are not only important vegetables, but the former is a raw material for the manufacture of starch and alcohol, and the latter is the source of a large part of the world's supply of sugar.

The potato and sweet potato are identified by the starch grains; the beet, carrot, and turnip by the vessels.

POTATO.

The potato (*Solanum tuberosum* L. order *Solanaceæ*), a native of South America, was introduced into Europe in 1560–1570, and was

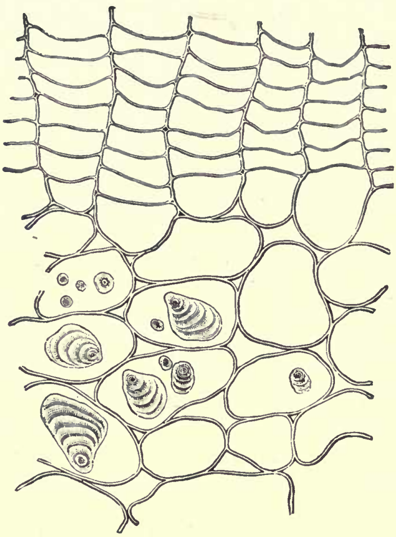

FIG. 316. Potato (*Solanum tuberosum*). Cross section of tuber showing cork cells and starch parenchyma. ×160. (MOELLER.)

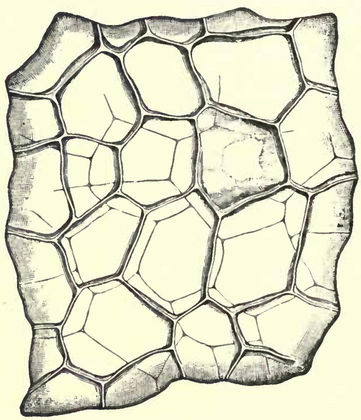

FIG. 317. Potato. Cork tissue in surface view. ×160. (MOELLER.)

first cultivated on a considerable scale in Italy and Holland. For the past hundred years it has been one of the most valuable of cultivated plants throughout the temperate zone, the tubers serving as a vegetable

[1] The descriptions of tubers and roots are by PROF. J. MOELLER.

and for the manufacture of starch, glucose and alcohol. The tubers differ in form and size, also in the texture, color and flavor of the flesh. They bear numerous "eyes" or buds in depressions on the surface.

HISTOLOGY.

Cork. The protective coat on the surface is a cork tissue (Fig. 316), with large cells, which in surface view are polygonal (Fig. 317).

Parenchyma. The outer layers are tangentially elongated, and contain proteid matter in the form of small aleurone grains. Further inward the cells are large, isodiametric, with intercellular spaces. They are filled with starch grains, most of which are large, irregularly pear-shaped, with distinct rings and an excentric hilum located in the small end (See p. 659).

DIAGNOSIS.

The starch grains (Fig. 581) are highly characteristic.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Moeller (29); Planchon et Collin (34).

JAPANESE POTATO.

Under this name are known the tubers of an Asiatic plant (*Stachys Sieboldii* Miq., order *Labiatæ*). They are 2–5 cm. long, 1 cm. thick,

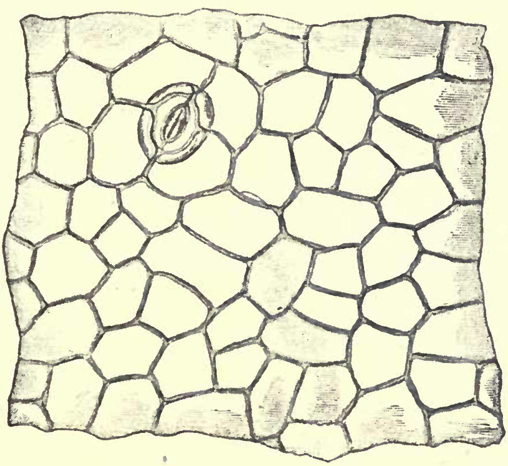

FIG. 318. Japanese Potato (*Stachys Sieboldii*). Epidermis of tuber in surface view. (MOELLER.)

and are divided into joints by constrictions, in each of which are two opposite membranaceous leaves.

HISTOLOGY.

The Epidermis (Fig. 318) consists of irregularly polygonal cells and a few stomata.

Between the *Fibro-vascular Bundles* are numerous small sieve tubes.

The Parenchyma of the flesh consists of unusually small cells, containing a soluble carbohydrate, stachyose. In tubers dug in the spring, starch is present.

JERUSALEM ARTICHOKE.

The tubers of *Helianthus tuberosus* L. (order *Compositæ*), a North American plant, are of some importance as food for both man and cattle. They are red-brown, elongated, often pear-shaped, and bear small roots, warty sprouts, and transverse rings. The flesh is white or red.

HISTOLOGY.

The bark is scarcely 1 mm. thick.

1. *The Epidermis* (Fig. 319), which is easily removed, consists of large, polygonal, slightly thickened cells, and here and there cork tissue with large cells.

2. *Cortex* (Fig. 319). The cells are quadrilateral, and often trans-

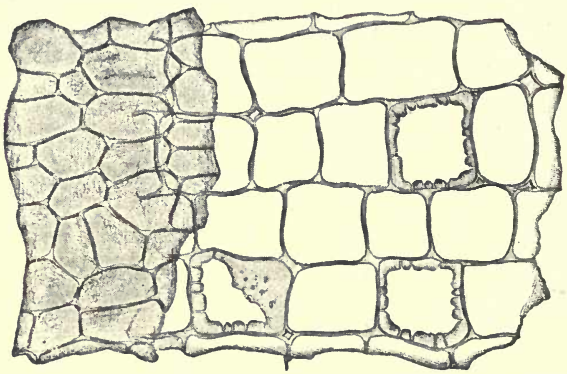

FIG. 319. Jerusalem Artichoke (*Helianthus tuberosus*). Epidermis and one of the parenchyma layers of tuber in surface view. (MOELLER.)

versely elongated. Some of them have somewhat thickened, sclerenchymatized walls.

3. *The Bast* contains balsam ducts, but no bast fibers.

4. *Xylem.* Within the indistinct cambium are irregular groups of vessels, often in radial rows. The cavity is narrow; the walls have thick

reticulations. Large, rather thick-walled cells containing inulin constitute the medullary rays.

DIAGNOSIS.

The balsam tubes, the quadrilateral stone cells of the cortex and the narrow reticulated vessels serve for identification.

BEET.

The roots of the common beet (*Beta vulgaris* L., order *Chenopodiaceæ*), and particularly the exhausted residue from the beet-sugar factories, are used both as cattle foods and as adulterants of chicory.

HISTOLOGY.

The Cork (Fig. 320) forms a thin outer zone of large cells with thick walls. By far the larger part of the root consists of *Parenchyma* (Fig. 321, *p*), the cells of which are about 250 μ in diameter, with walls 5 μ thick. On warming with water or soaking for a short time in alkali, intercellular material is evident.

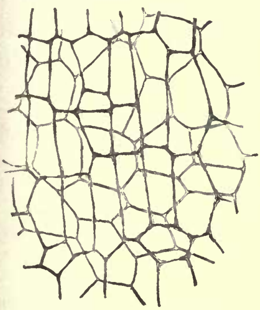

FIG. 320. Beet (*Beta vulgaris*). Cork layers of root in surface view. ×160. (MOELLER.)

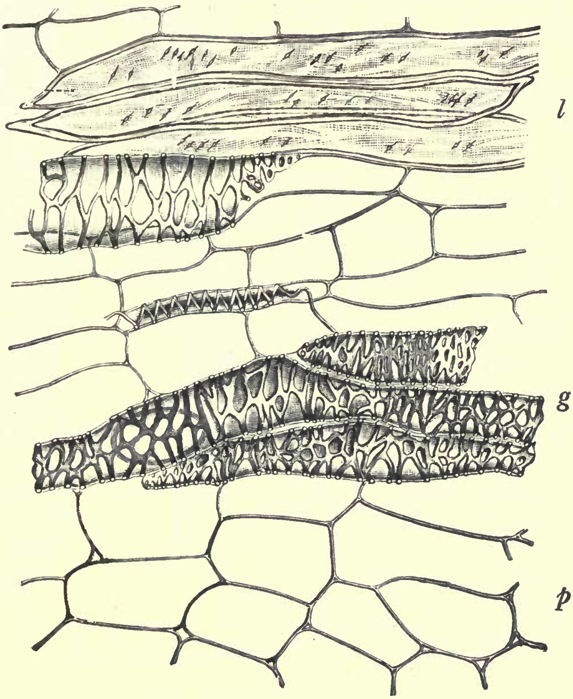

FIG. 321. Beet. Longitudinal section of root. *p* parenchyma; *g* reticulated vessels; *l* bast fibers. ×160. (MOELLER.)

The Vessels (Fig. 321, *g*) are mostly 50 μ, occasionally up to 100 μ, the reticulations forming broad meshes.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Hanausek, T. F. (16); Macé (26); Moeller (29); Planchon et Collin (34); Vogl (45, 48).

CARROT.

Occasionally the carrot (*Daucus Carota* L., order *Umbelliferæ*) is employed as an adulterant of chicory.

HISTOLOGY.

The Cork and *Parenchyma* are similar to those of the beet, but the

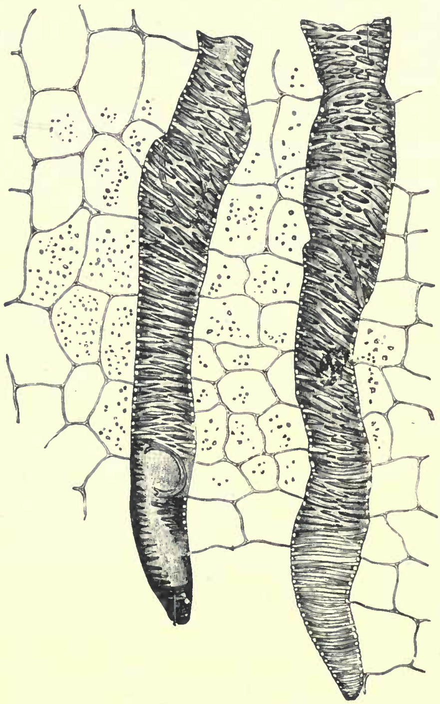

FIG. 322. Carrot (*Daucus Carota*). Longitudinal section of root showing parenchyma and reticulated vessels. ×160. (MOELLER.)

parenchyma consists of smaller cells, which contain yellow chromoplasts suspended in the cell sap.

The Vessels (Fig. 322, *g*) are seldom over 50 μ broad, and are characterized by their narrow elongated pores, resembling those in the vessels of the dandelion root.

BIBLIOGRAPHY.

See Bibliography of Beet.

TURNIP.

The white turnip (*Brassica Rapa* L., order *Cruciferæ*) serves as a food for man and beast, also as an adulterant of coffee, horseradish, etc.

HISTOLOGY.

The cork is similar to that of the beet, but the cells are smaller. More characteristic are the cells of the *Parenchyma* (Fig. 323, *p*), which are

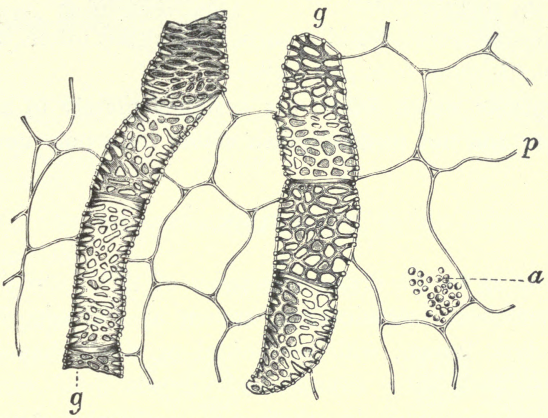

FIG. 323. White Turnip (*Brassica Rapa*). Longitudinal section of root. *p* parenchyma; *g* reticulated vessels; *a* starch grains. ×160. (MOELLER.)

exceptionally large (commonly 500 μ) and thin-walled (2 μ). They contain small aleurone grains, and here and there crystal sand (calcium oxalate).

The Vessels (*g*) consist of short joints, and have narrow, rounded pores resembling those of chicory.

BIBLIOGRAPHY.

See Bibliography of Beet.

FUNGI.[1]

Edible fungi when whole and fresh may usually be distinguished by their gross appearance. Only in the examination of the dried material

[1] The descriptions of the individual fungi are by PROF. J. MOELLER.

or food products containing sliced or minced fungi is the microscope essential.

The common species found on the market belong in the following subclasses and orders:

Ascomycetes: Spores produced within sacs (asci.)

1. Discomycetes: Asci borne on the outer surface of various shaped fructifications (e.g., Morel).
2. Tuberaceæ: Asci borne within a tuberous fructification (e.g., Truffles).

Basidiomycetes: Spores produced on the surface of sacs (basidia).

1. Hymenomycetes: Basidia borne within the (usually umbrella-shaped) fructification on gills (e.g., common mushroom), rods (e.g., Boletus), etc.
2. Gasteromycetes: Basidia borne within the (often tuber-shaped) fructification (e.g. puff-balls).

The descriptions which follow are designed merely to aid in detecting adulteration and not to distinguish edible from poisonous species.

TRUFFLES.

Fungi belonging to the order *Tuberaceæ* of the *Ascomycetes* develop underground tuberous fructifications known as truffles. These bodies are black or dark brown, with pyramidal or shield-shaped, polygonal warts. Cross sections show cavities or channels lined with masses of hyphæ tissues (hymenium), in which are borne club-shaped elements (asci), each containing 1–4 (seldom more) unicellular spores (Fig. 325). The size, form, color and markings of the spores furnish the best means for identification of the species. They are obtained for study either by cutting sections of the inner tissues, or by scraping the inner surface. The following are the common species.

1. **French or Perigord Truffles** (*Tuber brumale* Vitt.) because of their fine flavor are the most highly prized of the group. They grow mostly under oaks in France, Northern Italy, and Southern Germany. The fruit bodies vary from the size of a hazelnut to that of an apple. On the surface they are black, with well-defined warts; within they are dark violet or red-black. The spores are coffee-brown, elliptical, 25–45 μ long, thickly beset with prickles (Fig. 326, *d*). The true perigord truffle (var. *Melanospermum*) has dark, very aromatic flesh, and almost black, often large spores (Fig. 326, *c*).

2. **German or Hanover Truffles** (*Tuber æstivum* Vitt., also var. *mesentericum* and *uncinatum*) are less aromatic than the preceding. They are obtained from Northern Italy, France, Germany, Switzerland, and Bohemia. The flesh is lighter than that of French truffles, and the yellow or coffee-brown spores (Fig. 326, *a*, *b*) are characterized by their broad reticulations.

FIG. 324. German Truffles (*Tuber æstivum*). Vertical section showing rind, air passages, dark veins of compressed hyphæ, and masses of asci. Natural size. (TULASNE.)

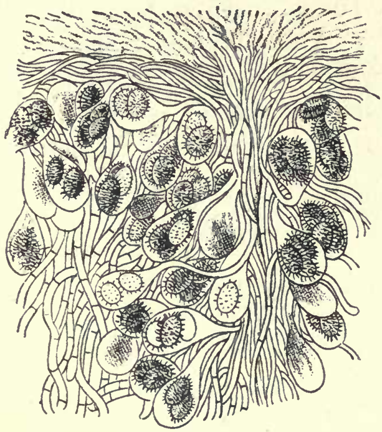

FIG. 325. French Truffles (*Tuber brumale*). Section showing hyphæ and spore-bearing asci. ×400. (TULASNE.)

DIAGNOSIS.

Whole truffles cannot be successfully adulterated, but in the dried condition other fungi are often substituted. Truffled patés frequently contain these substitutes. They are detected by their color and the

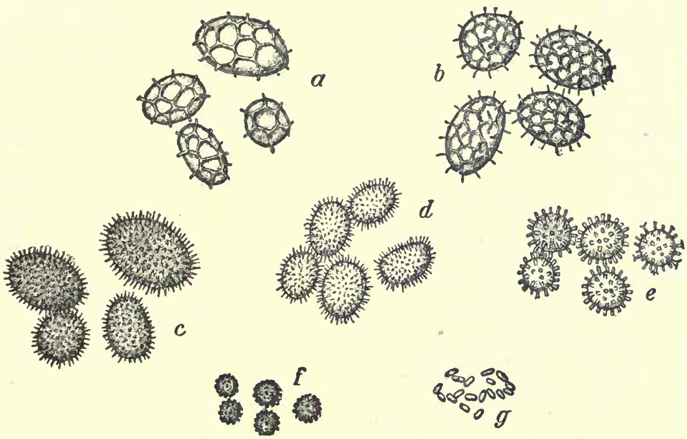

FIG. 326. Spores of Truffles and Substitutes. *a* and *b* German Truffles; *c* and *d* French truffles; *e* white truffles; *f* false truffles (*Scleroderma*); *g* false truffles (*Rhizopogon*). (MEZ.)

characters of the spores, although it is difficult or impossible to determine the exact species.

The following are the common substitutes:

1. White Truffles (*Choiromyces maeandriformis* Vitt.) are found in England and middle Europe. They are light yellow-brown, and resemble potatoes in external appearance. The flesh is white to brown, with brown veins, and is but slightly aromatic. The small (15–20 μ) globular spores are light brown, beset with numerous prickles of unequal length (Fig. 326, *e*).

2. False Truffles (*Scleroderma vulgare* Hornem.—*Gasteromycetes*) are aerial, tuberous bodies about the size of genuine truffles, with a skin 2–3 mm. thick. Within, the tissues are at first white, later gray to black. The small spores are globular, black, with prickly warts (Fig. 326, *f*). They can only be used green, in which state they have a disagreeable flavor quite unlike that of real truffles.

3. Species of *Rhizopogon* (*Gasteromycetes*) develop under ground tuberous bodies, externally similar to those of *Scleroderma*. They have a membranous or leathery periderm difficultly separable from the flesh, and very small, ellipsoidal, smooth, almost colorless spores (Fig. 326, *g*).

4. Species of *Elaphomyces* are closely related to real truffles. Their fruit bodies develop under ground, and on ripening are converted into a powdery mass. They are not edible.

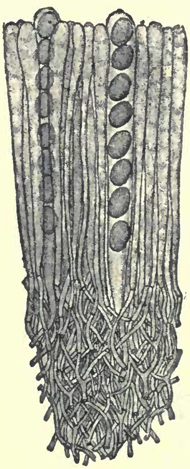

Fig. 327. Common Morel (*Morchella esculenta*). Cross section through hymenium, showing asci and paraphyses. (Mez.)

MORELS.

The morels belong to the order *Discomycetes*, of the subclass *Ascomycetes*. The fleshy, club-shaped or globular head is borne on a stalk. The hymenium (Fig. 327) covers the reticulated outer surface of the head, and consists of a palisade-like layer of asci and paraphyses, each of the former containing eight smooth, mostly ellipsoidal spores.

The following species are of importance:

1. **The Common Morel** (*Morchella esculenta* Pers.) has a hollow stalk, yellow to brown head, and ochre-colored spores.

2. **The Spring Morel** (*Gyromitra esculenta* Fr.) has a hollow stalk, hollow or collapsed coffee-brown head, and white spores.

3. **The Autumn Morel** (*Helvella Infula* Schäffer) has a thin brown head united only in the middle with the stalk, and white spores.

All the species are edible, although the spring morel and some others must be first treated with hot water to remove a poisonous principle, which also disappears slowly on drying.

MUSHROOMS.

These are umbrella-shaped, and bear the hymenium on the under surface of the head. They belong to the order *Hymenomycetes* of the subclass *Basidiomycetes*.

1. **The Field Mushroom** (*Psalliota campestris* Fr., *Agaricus campestris—Agaricineæ*) has when young a globular head, which later becomes spreading, reaching 15 cm. in breadth. The upper surface is brownish; the flesh is white. On the under surface are numerous spore-bearing gills, which are at first pink, but later are brown, as are also the elliptical spores (8:6 μ). The stalk is white, 6–8 cm. long, with a thick membranous ring (volva) near the center. Cross-sections through the lamellæ show in the middle a layer of broad hyphæ (Fig. 329), flanked on both sides by small hyphæ from which spring the basidia, also the sterile bodies known as paraphyses. The spores are borne on the surface of the basidia.

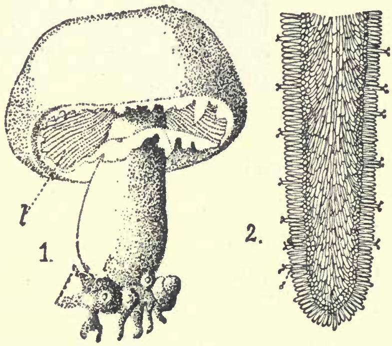

FIG. 328. Field Mushroom (*Psalliota* (*Agaricus*) *campestris*). 1 Natural size, showing *l* lamellæ. 2 Cross section of a lamella, magnified. (SACHS.)

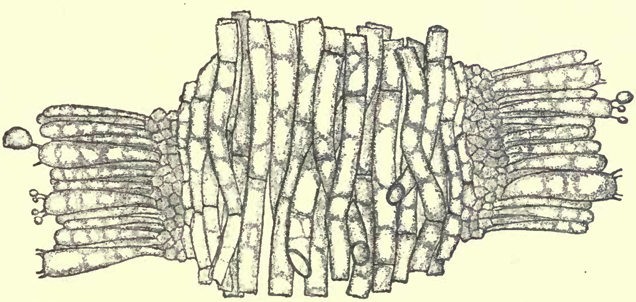

FIG. 329. Field Mushroom. Cross section of a lamella, strongly magnified. (MEZ.)

The poisonous *Amanita phalloides* Quél (*A. bulbosa* Bull.) has a bulbous thickening at the base of the stalk, bordered by a sac-like membrane, also white spores. Cross sections of the lamellæ show that the middle hyphæ layer is surrounded by hyphæ spreading out in bows (Fig. 330).

2. **Boletus edulis** Bull. (*B. bulbosus* Schäff.—*Polyporeæ*) and other edible species of *Boletus*, are distinguished from the species of the *Agaricineæ*

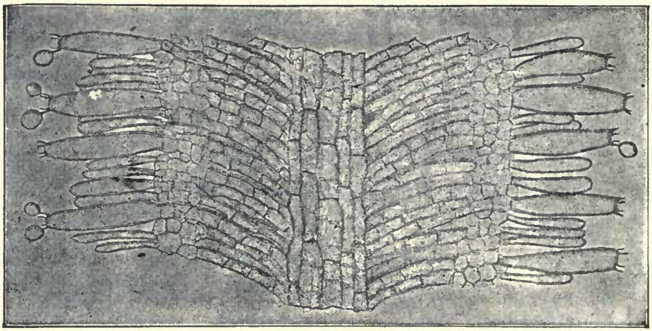

FIG. 330. Poisonous Amanita (*A. phalloides*). Cross section of a lamella. (MEZ.)

by the thick swollen stalk, and the dependent tubes on the under surface of the head. The brown head is at first semiglobular, later spreading, reaching 20 cm. Its flesh is white, and does not greatly change in color on exposure. The tube layer, which is easily removed from the under side of the head, is at first white, later yellow or green-yellow. The spores are spindle-shaped, smooth, yellow or brown.

PART VIII.

ALKALOIDAL PRODUCTS AND THEIR SUBSTITUTES.

ALKALOIDAL PRODUCTS.[1]

Savage and civilized nations alike are addicted to the use of alkaloidal as well as alcoholic stimulants. The American aborigines long before the discovery of the continent by Columbus were acquainted with the virtues of the cocoa bean and the tobacco leaf, and the natives of West Africa have for centuries chewed the cola nut. The products here described include those containing caffein, theobromin and nicotine, also certain substitutes free from alkaloids. Opium and other more potent alkaloidal products are considered in works on pharmacognosy.

COFFEE.

Coffee, next to sugar the most important product imported from the tropics, is the seed of a small tree or shrub, *Coffea Arabica* L. (order *Rubiaceæ*), a native of Abyssinia and other parts of Africa. In the fifteenth century the tree was introduced into Arabia, where the beverage became popular with all classes, notwithstanding the opposition of the Mohammedan priests. Coffee drinking was soon taken up by all the Saracenic races and later by the European nations.

For over two hundred years the culture of the coffee tree was limited to Arabia, but in the latter part of the seventeenth century it was successfully undertaken by the Dutch in Java, and somewhat later in Surinam, and the industry soon spread over Sumatra, India, Ceylon, Western Africa, and other parts of the Eastern Hemisphere, as well as over the West Indies and the tropical parts of South America. To-day Brazil leads the world in coffee production, although the choicest grades come from Arabia (genuine Mocha coffee) and Java.

The white and delightfully fragrant flowers of the coffee tree are produced in the axils of the leaves. The fruit (Fig. 331) is about the size of a small cherry, and is red or purple when fully ripe. It normally

[1] The descriptions of tea, tobacco, and all other leaves, also of chicory, dandelion, guarana, and cola nut are by PROF. J. MOELLER.

contains two cells, each with a single plano-convex seed (Figs. 331 and 332) so situated that the flat surfaces of the two seeds adjoin one another,

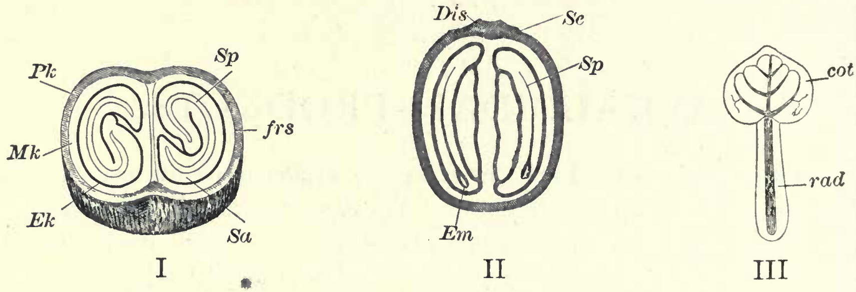

FIG. 331. Coffee (*Coffea Arabica*). *I* cross section of berry, natural size. *Pk* outer pericarp; *Mk* endocarp; *Ek* spermoderm; *Sa* hard endosperm; *Sp* soft endosperm. *II* longitudinal section of berry, natural size; *Dis* bordered disc; *Se* remains of sepals; *Em* embryo. *III* embryo, enlarged: *cot* cotyledon; *rad* radicle. (TSCHIRCH and OESTERLE.)

but in the so-called peaberry coffee, one of the ovules is abortive, the other developing into a rounded seed filling the single cavity. The outer portion of the fruit is dark colored and pulpy, lined by a buff, parchment-like endocarp. The seeds, which before roasting are yellow or light green, have a longitudinal cleft on the flattened side due to the folding of the endosperm. A papery spermoderm, known as the silver skin, covers not only the outer surface but penetrates also the cleft. The minute embryo (Fig. 331, *II Em*, *III*) is situated in the endosperm near the base of the seed.

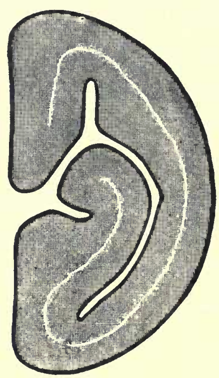

FIG. 332. Coffee. Cross-section of bean showing folded endosperm with hard and soft tissues. ×6. (MOELLER.)

Various processes, some dry, others wet, are employed for removing the pericarp and spermoderm from the seed. In the West Indies and South America, the larger part of the fruit flesh is first removed by a pulper, after which the pulp still adhering is loosened by a fermentation process and washed away by water. After drying, the spermoderm and endocarp are broken away from the seed and separated by winnowing. The spermoderm is also removed from the surface but not from the cleft. Roasting swells the seed greatly, changes its color to dark brown, and develops the characteristic odor and flavor of roasted coffee by the formation of caffeol and other substances.

HISTOLOGY.

As fresh material is not obtainable in the temperate zone except from botanical gardens, alcoholic or dried specimens must be used for histological studies.

Coffee beans, as found on the market, whether unroasted or roasted, consist only of the endosperm, embryo, and that portion of the spermoderm within the cleft, although occasionally fragments of the pericarp occur with the beans as an accidental impurity. The pericarp may be sectioned dry, the endosperm after soaking in water.

The Pericarp after drying is of a dark color about 0.5 mm. thick. As the outer layers are soft and the endocarp hard, no little difficulty is experienced in preparing sections. For cutting transverse sections, the dry material freed from the seed may be embedded in hard paraffine and cut with a strong razor or microtome knife, taking care that the palisade cells and endocarp, which are liable to separate from the outer layers, are not lost. Staining with safranin, naphthylene blue or methylene blue is recommended.

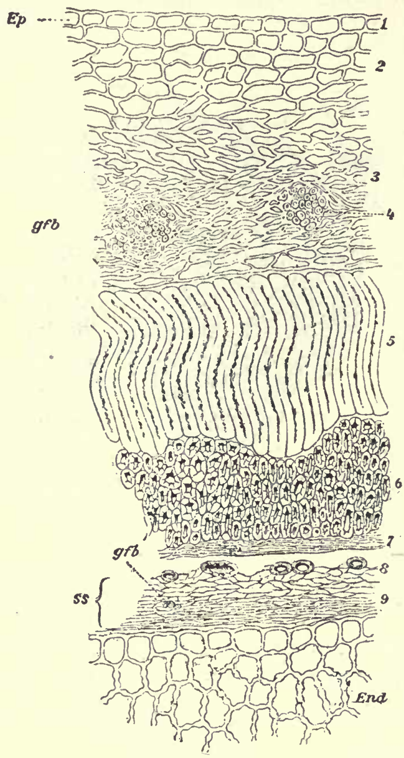

FIG. 333. Coffee. Cross section of hull and bean. Pericarp consists of *1* epicarp, *2*, *3* layers of mesocarp with *4* fibro-vascular bundle, *5* palisade layer, and *6* endocarp; *ss* spermoderm consists of *8* sclerenchyma and *9* parenchyma; *end* endosperm. (TSCHIRCH and OESTERLE.)

1. *The Epicarp Cells* (Figs. 333 and 334, *ep*) are 15–35 μ broad, sharply polygonal, occasionally four-sided, with brown walls and contents. Stomata with two accompanying cells similar to the guard cells in form occur here and there.

2. *Mesocarp* (Figs. 333, 334, and 335). Proceeding inward, the cells increase in size until they reach a maximum of about 100 μ. Their walls are thick and either brown or yellow. Brown amorphous masses and occasionally large crystals are noticeable in the outer layers. In

the innermost part of the mesocarp, through which ramify the fibro-vascular bundles, the cells are commonly compressed. The strongly developed bundles contain bast fibers up to 1 mm. long and 25 μ broad, with thick walls and narrow lumen, spiral vessels mostly narrower than the bast fibers, but with noticeably thick spirals, pitted vessels, and other less conspicuous elements.

3. *Palisade Layer* (Fig. 333, *5*). These cells are greatly elongated in radial directions and have walls of mucilaginous structure which swell

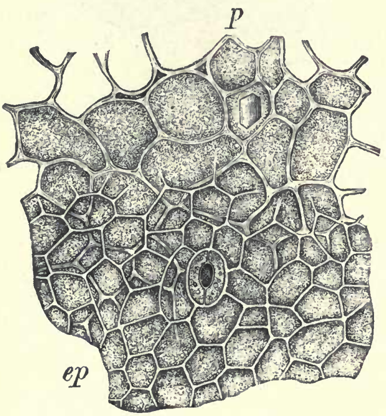

FIG. 334. Coffee. Surface view of *ep* epicarp and *p* outer parenchyma of mesocarp. ×160. (MOELLER.)

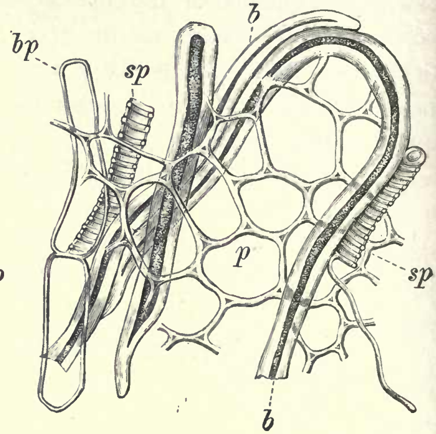

FIG. 335. Coffee. Elements of pericarp in surface view. *p* parenchyma; *bp* parenchyma of fibro-vascular bundle; *b* bast fiber; *sp* spiral vessel. ×160. (MOELLER.)

in water. Because of these peculiarities, as well as the difficulties of cutting so soft a tissue when adjoining a hard coat like the endocarp, special care must be exercised in preparing sections. Safranin stains the swollen wall carmine, but does not affect the yellowish contents. Vogl states that naphthylene blue colors both the walls and contents blue-violet.

4. *Endocarp* (Fig. 333, *6*; Fig. 336). Closely united with the palisade layer is the thin, but hard, buff-colored endocarp resembling in macroscopic and microscopic structure the endocarp of the apple. The fibers cross one another at various angles, but in the outer layers their general direction is longitudinal, while in the inner layer it is transverse. The fibers of the inner layer are thin-walled, whereas those of the other layers are thick-walled and conspicuously porous.

Spermoderm. Although the spermoderm is removed from the surface of most of the seeds in preparing them for market, fragments sufficient for study may often be obtained from unroasted coffee. Within the cleft the spermoderm is almost always intact, even after roasting,

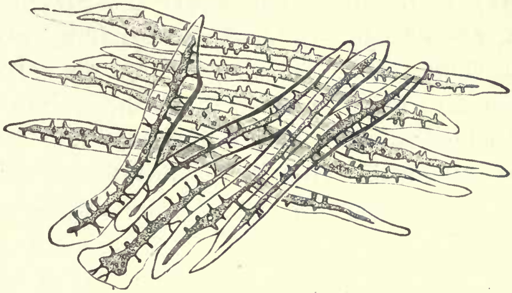

FIG. 336. Coffee. Sclerenchyma fibers of endocarp. ×160. (MOELLER.)

and may be readily removed in one piece after soaking the seed for some hours in water.

1. *Sclerenchyma Cells* (Fig. 333, *8*; Fig. 337, *st*) form the characteristic outer layer. In the early stages of development the coat is uninter-

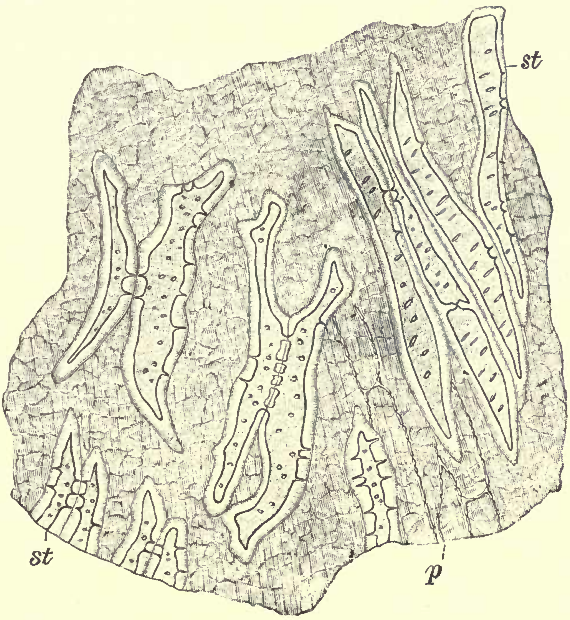

FIG. 337. Coffee. Spermoderm in surface view. *st* sclerenchyma; *p* compressed parenchyma. ×160. (MOELLER.)

rupted, but in the mature seed, as a result of more rapid growth of adjoining tissues, they are more or less detached, occurring singly, in pairs or in groups, either widely separated or with only small intercellular spaces between them. They vary from less than 100 μ to over 1 mm. in length and from 15–50 μ in breadth. The longer cells, occurring in groups within the cleft, are straight and narrow, resembling bast fibers, while the medium and shorter cells, occurring both on the surface and in the cleft, are broader and more irregular in outline, vermiform and club-shaped forms predominating, although triangular and various fantastic shapes are not uncommon. Great variations in the thickness of the walls and the size and number of the pores are also noticeable.

2. *Parenchyma Cells* (Fig. 333, *g*; Fig. 337, *p*), more or less obliterated, form the remainder of the spermoderm. Occasionally cells with beaded walls are distinguishable, but in most parts the cells are not clearly evident, the tissue appearing like a structureless membrane. Through this tissue in the cleft runs the raphe, with narrow spiral vessels, which are best seen after treatment with alkali or chloral hydrate.

Endosperm (Figs. 333 and 338). Coffee, like the date stone and the ivory-nut, contains only the minutest traces of starch, the carbohydrate

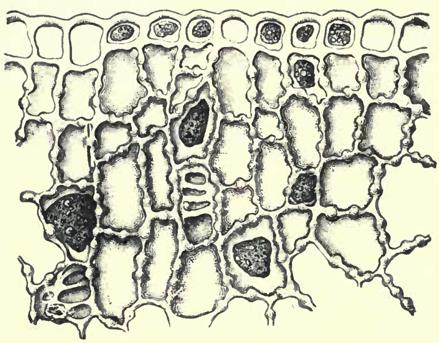

FIG. 338. Coffee. Cross section of outer layers of endosperm showing knotty thickenings of cell walls. ×160. (MOELLER.)

reserve material being largely in the form of cellulose stored up in the cell-walls of the endosperm. In sections, the cell-walls, except in the outer layers, appear to be knotty-thickened, owing to the large pores by which they are pierced, the double walls in the knots ranging up to 20 μ in thickness. The cells are smallest in the cuticularized outer layer, where they are 15–50 μ in diameter, but in the inner layers they often reach 100 μ. To the naked eye the central portion of the endosperm (Fig 332) has a somewhat different appearance from the remainder, due to the presence of an interrupted series of tangentially elongated cells, the walls of which, excepting the middle lamella, are composed of a mucilaginous substance, and consequently disappear on treatment with water. It is in this mucilaginous tissue near the base that the minute embryo is embedded. Tschirch regards this soft tissue as useful in facilitating the absorption of the reserve material by the sprouting plantlet.

Treatment with various reagents and stains, such as chlorzinc iodine, iodine-sulphuric acid, naphthylene blue, and safranin, show that the thickened cell-walls consist of cellulose. Reagents also serve for the identification of the cell-contents. For example, concentrated sulphuric acid produces a fine red color showing the presence of sugars, iron salts give a green color due to tannic acid, various reagents show the presence of proteids, sometimes in the form of aleurone grains, while numerous micro-tests given by Tschirch and Oesterle confirm the presence of caffein. Vogl notes that sections are colored an intense yellow by caustic potash and soda, and a green-yellow changing to green by ammonia. Heating with chloral hydrate imparts a blue-green coloration to the contents, but this reaction, as well as some of the others, is not distinct in the case of roasted coffee, and is therefore of no practical value.

The Embryo (Fig. 331, *III*) may be obtained by cutting a bean, previously soaked overnight in water, through the cleft and carefully splitting open the endosperm through the mucilage cells. After longer soaking in water or in dilute alkali, the embryo bursts through the endosperm at the basal end. The blunt radicle is 3–4 mm. long, the heart-shaped cotyledons 1–2 mm. long. After clearing with alkali, or better with Javelle water or chloral hydrate, the cotyledons are seen to have three pairs of sparingly branching nerves. The small cells and procambium bundles filled with protoplasm and fat are of little diagnostic importance (Fig. 339).

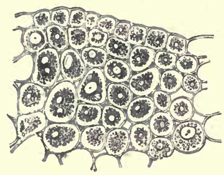

FIG. 339. Coffee. Tissues of embryo in section. ×160. (MOELLER.)

DIAGNOSIS.

Coffee reaches the consumer either "green" (unroasted) or roasted, and in the latter case either whole or ground. Roasting, as ordinarily conducted, changes the color of the bean to a rich brown which renders most of the microchemical tests of little value, but does not seriously obscure the structure of either the spermoderm or endosperm.

Whole Coffee, also known as "coffee beans" and "coffee berries," is characterized by the form and horny texture of the endosperm, and the presence of the spermoderm or "chaff" in the cleft. The spermoderm without special preparation is readily identified under the microscope by the more or less isolated sclerenchyma cells; the endosperm, in section, by the knotty-thickened walls, and the absence of more than the faintest trace of starch.

The adulteration of genuine coffee with beans previously used for the manufacture of coffee extract cannot be detected by microscopical examination, although the coating of these beans, as well as of inferior grades of unextracted coffee, with various pigments, is sometimes evident in microscopic sections.

Ground Coffee varies in fineness from coarsely crushed beans to a powder passing a 1 mm. sieve. Usually there is an abundance of fragments large enough to section with a razor, either dry or after soaking, thus permitting an examination of the cell-walls of the endosperm (Fig. 338). The papery flakes of spermoderm (Fig. 337) may be picked out with forceps.

If a handful is stirred with cold water, true coffee, except for a few over-roasted fragments, floats; whereas the common adulterants, including peas and other legumes, cereal grains, chicory and other roots, imitation coffee, etc., sink rapidly to the bottom, their nature being determined by microscopic examination. Artificial coffee made from oil-seed products is said to float.

Outer Coffee Hulls, consisting of the epicarp, the mesocarp, and traces of the palisade layer, are utilized by the Arabians in the preparation of a fermented liquor, "Kischer" or "Gischr." These hulls are also exported from coffee-growing regions under the names "Sultan coffee," and "sacca-coffee," as an adulterant of coffee, the fact that they are a product of the coffee tree and the claim that they contain a certain amount of caffein and other valuable constituents being offered as excuses for their use. These claims are not worthy of consideration, as the product is even more worthless than most of the common substitutes.

The hulls occur in small amount in genuine coffee, but when the amount is considerable, adulteration is indicated. They are of a black color, with a small ring about 2 mm. in diameter at the upper end, in the middle of which is the scar of the style. Highly characteristic elements being absent, it is often difficult to identify the material in powder form. The epicarp (Fig. 334, *ep*) and brown mesocarp resemble the corresponding tissues of the carob bean, though the epicarp of coffee may be distinguished by the stomata with two adjoining cells and the thicker-walled mesocarp, the contents of which do not give the blue or violet color on warming with alkali.

Inner Coffee Hulls, consisting of endocarp with particles of the adhering palisade layers, are parchment-like in texture and of a buff color. Although they have scarcely more value than sawdust, they have been used in the United States as an adulterant of wheat bran and other cattle foods. Charred hulls have recently been detected by the writer in ground pepper. This material is characterized by the groups of crossing fibers (Fig. 336).

Artificial Coffee Beans moulded from dough, sometimes with the admixture of chicory and other materials, resemble genuine roasted beans in form and color, but are distinguished by the exact correspondence of beans from the same mould, the shallow cleft, the absence of chaff in the cleft, the granular texture, and other physical characteristics which can be learned only by experience. As usually prepared, they sink at once in cold water. Under the microscope, starch and other elements of the constituents are identified.

Artificial Broken Coffee similar to the artificial beans, but made in irregular lumps, not moulded in the forms of beans, resembles closely broken coffee beans and serves as an adulterant both for whole and ground coffee. Another form of artificial coffee much used in America consists of pea hulls, cereal matter, and molasses, made into small pellets.

The Fruits and Seeds used most commonly as substitutes or adulterants of coffee are wheat, rye, barley, maize, and other cereals, also cereal products, such as bran, middlings, bread, etc.; peas, beans, lupines, cassia seeds, astragalus seeds, Parkia seeds, chick peas, soja beans, peanuts, and other leguminous seeds; dried figs, prunes, pears, bananas, and carob bean pods; date stones, ivory nuts, acorns, grape seeds, fruit of the wax palm, cola nut (*Mussaende-Kaffee*), and false flax.

Roots. Chicory is by far the commonest root used in coffee. It is gummy, sweet to the taste, colors cold water a deep yellow, and is identified by the vessels and latex cells. Other roots used are dandelion, beet, turnip, and carrot, all of these being adulterants of chicory.

Coffee Substitutes (European). Among the hundreds of proprietary articles sold in Europe as substitutes for coffee are the following: "Kanon" (rye, coffee, chicory); "Datel Kaffee" (wheat, chicory, figs, and coffee); "Homeopathischer Gesundheitskaffee" (wheat, chicory, and cocoa shells); "Hygienischer Nährkaffee" (cereals and acorns); "German Soda Coffee" (cereals, chicory, and sodium carbonate); "Jamaika Kaffee" (barley); "Mokka-Sakka-Kaffee" (barley and other constituents); "Saladinkaffee" (maize); "Malto-Kaffee" (malt or mixtures of malt and other cereals); "Kraft-Kaffee," "Frucht-Kaffee" and "Allerwelts Kaffee" (lupine seeds); "Mogdad," "Neger," and "Stephanie-Kaffee" (seeds of *Cassia occidentalis* and *C. sophora*); "Sudan-Kaffee" (seeds of *Parkia Africana* and *P. biglobosa*); "Schwedische Kontinental-Kaffee" (seeds of *Astragalus boeticus*); "Deutscher" or "Französischer Kaffee" (chick pea); "Ungarischer Kaffee" (coffee, lupines, and chicory); "Africanischer Nussbohnen Kaffee" (peanuts); "Bayrischer Kaffee" (beets, figs, rye, and legumes); "Mokara" or "Feigenkaffee" (figs); "Figine" (figs and chicory); "Melilotin Kaffee" (coffee, chicory, and date stones); "Almond Coffee" (originally made of the tubers of *Cyperus esculentus* L., later of acorns, chicory, and dandelion root); "Frank Kaffee" (chicory); "Café de Rheims" and "Rations Coffee" of the French army (coffee and chicory); "Domkaffee" (chicory).

Coffee Substitutes (American). Among the preparations made in the United States, the following have been found to consist of various preparations of cereals: "Ralston Cereal Coffee," "Grain-O," "Postum Cereal Coffee," "Ayer's Hygienic Substitute for Coffee," "New Era Hygienic Coffee," "Shredded Cereal Coffee," "J. W. Clark's Phosphi Cereal Nervine Coffee," and many others. Other preparations are: "Old Grist Mill Entire Wheat Coffee" (wheat, peas, and real coffee); "Fischer Mills Fresh Roasted Malt Coffee;" "Kneipp Malt Coffee" (barley or malt); "Kentucky Coffee" (*Caesalpinia pulcherrima*).

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Berg (3); Greenish (14); Hanausek, T. F. (10); Hassall (19); Leach (25); Macé (26); Moeller (29, 30, 31, 32); Molisch (33); Planchon et Collin (34); Schimper (37); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (43, 45).

BRUNOTTE: A Pseudo-substitute of Coffee. Rev. internat. falsificat. 1896, **9**, 48.

CAZENEUVE: Artificial Coffee Beans. Petit mon. de la pharm. 1894, 1513.

COSTER, HOORN u. MAZURE: Falsifications observées en Holland. Rev. internat. falsificat. 1887–88, **1**, 162. 1890, **4**, 7.

CRIBB: Note on (1) Samples of Coffee Containing Added Starch; (2) Sample of Artificial Coffee Berries. Analyst. 1902, **27**, 114.

DRAPER: Detection of Coffee Adulterations. Phil. Mag. **34**, 104.

DUSTAN: Der sogenannte Mussaenda-Kaffee von Réunion. Ztschr. Nahr.-Unters. Hyg. 1890, **4**, 13.

FRICKE: Sogenannter Congo-Kaffee. Ztschr. angew. Chem. 1889, **2**, 121.

GAWALOWSKI: Ersatzmittel für Kaffeebohnen. Ztschr. Nahr.-Unters. Hyg. 1896, **9**, 123.

GREINERT: Ueber Negerkaffee. Pharm. Ztg. 1889, **34**, 192.

GUNDRISER: Ueber ein Kaffeesurrogat aus den Samen der blauen Lupine (*Lupinus angustifolius*). Ztschr. Nahr.-Unters. Hyg. 1892, **6**, 373.

HANAUSEK, E.: Künstliche Kaffeebohnen. Ztschr. Nahr.-Unters. Hyg. 1890, **4**, 25, 172.

HANAUSEK, T. F.: Dattelkerne als Kaffeesurrogat. Chem. Ztg. 1886, **10**, 701.

HANAUSEK, T. F.: Künstliche Kaffeebohnen. Ztschr. Nahr.-Unters. Hyg. 1889, **3**, 3.

HANAUSEK, T. F.: Die Entwicklungsgeschichte der Frucht und des Samens von *Coffea, arabica.* Ztschr. Nahr.-Unters. Hyg. 1890, **4**, 237, 257. 1891, **5**, 185, 218. 1893, **7**, 85, 195.

HANAUSEK, T. F.: Zum Bau der Kaffeebohnen. 66. Vers. deutsch, Naturf. u. Aerzte. Wien, 1894.

JAMES: Le café torrifié, engrains, factice. Revue d'hyg. 1890, No. 12.

KÖNIG: Kunstkaffee. Chem. Centralbl. 1889, **20**, 1, 51.

KÖNIG: Die Früchte der Wachspalme als Kaffeesurrogate. Centr.-Org. f. Waarenk. u. Techn. 1891, **1**, 1.

KORNAUTH: Communications diverses concernant les denrées alimentaires et les boissons. Rev. internat. falsificat. 1889–90, **3**, 195.

KORNAUTH: Beiträge zur chemischen und mikroskopischen Untersuchung des Kaffees und der Kaffeesurrogate. Hilger, Mitth. Lab. angew. Chem. Erlangen, III Heft. München, 1890, 1.

KORNAUTH: Zur Beurtheilungen der Kaffeesurrogate Ztschr. angew. Chem. 1891, 645.

MANSFELD: Bericht über die Thätigkeit der Untersuchungsanstalt des Allgemeinen österreichischen Apothekervereines und des Wiener Apotheker-Hauptgremiums. Ztschr. Nahr.-Unters. Hyg. 1896, **10**, 336.

MANSFELD: Kaffeesurrogate. Jahresber. Unters. allg. österr. Apoth.-Ver. 1901, 10.

MOELLER: Ueber Mogdad-Kaffee. Pharm. Centralh. **22**, 133. Dingler's Polytechn. Jour. 1880, **237**, 61.

MORPURGO: Eine einfache Methode zur Entdeckung künstlicher Färbungen der Kaffeebohnen. Ztschr. Nahr.-Unters. Hyg. 1898, **6**, 9.

NEVINNY: Die Nahrungs- und Genussmittel Wiens. Ztschr. Nahr.-Unters. Hyg 1887, **1**, 21.

NEVINNY: Zur Verfälschung des Feigenkaffees. Ztschr. Nahr.-Unters. Hyg. 1887, **1**, 85.

PADÉ: Neue Fälschungen des Kaffees. Chem. Centralbl. 1889, **20**, 2.

PORTELE: Künstliche Kaffeebohnen. Ztschr. Nahr.-Unters Hyg. 1889, **3**, 221.

RAUMER: Ein neues Kaffeesurrogate. Forschber. Lebensm. Hyg. 1894, **1**, 293.

RAUMER: Ueber den Nachweis künstlicher Färbungen bei Rohkaffee. Forschber. Lebensm. Hyg. 1896, **3**, 333.

REUTER: Beitrag zur Kenntniss der Bestandtheile des Mogdad-Kaffees. Pharm. Centralh. 1889, **30**, 494.

ROHRIG: Afrikanischer Nussbohnenkaffee. Forschber. Lebensm. Hyg. 1895, **2**, 15.

RUFFIN: Fabrikation, Veränderungen und Fälschungen der Cichorien. Ann. chim. anal. 1898, 3, 114.
SAMELSON: Ueber Kunstkaffee. Ztschr. angew. Chem. 1890, 482.
STREET: Coffee Hulls. New Jersey Agr. Expt. Sta. Bull. 160, 1902.
STUTZER: Ueber Kunstkaffee. Ztschr. angew. Chem. 1888, 1, 699. 1890, 549.
TRILLICH: Ueber Malzkaffee und Kaffeesurrogate. Ztschr. angew. Chem. 1891, 540.
TRILLICH: Kaffee und Kaffeesurrogate. Ztschr. angew. Chem. 1896, 440.
TRILLICH: Ueber Kaffee mit thränenförmigen Bohnen. Ztschr. öffentl. Chem. 1898, 542.
WAAGE: Ueber künstliche Kaffeebohnen. Apoth.-Ztg. 1890, 5, 219.
WOLFFENSTEIN: Untersuchung einiger Kaffeepräparate. Ztschr. angew. Chem. 1890, 84.

LIBERIAN COFFEE.

Liberian coffee (*Coffea Liberica* Bull.) is found wild and cultivated in Liberia and the whole of the Guinea coast. The limited product is exported chiefly to England and the Continent.

The fruit is extremely large, averaging 1 to 1¼ inches in length, ellipsoidal, and pointed at both ends. Compared with *C. Arabica* the pulp is thicker, the parchment hard and brittle, never clear, and the spermoderm or silver skin stronger, tougher and more tightly rolled into the deep, narrow furrow. The bean also is unusually large, peculiar in form, dark brown in color, and heavy in weight. Although coarser flavored, owing to its strength it is well adapted for admixture with better sorts.

Hartwich notes that the embryo of *C. Liberica* is 7.5 mm. long, that of *C. Arabica* only 4 mm.; also that the stone cells of the spermoderm are 880 μ long and 51 μ broad in the former, while they are but 484 μ long and 41 μ broad in the latter species.

BIBLIOGRAPHY.

HARTWICH: Coffea liberica. Schw. Woch. Chem. Pharm. 1896, 34, 473.

CHICORY.

The oldest and commonest substitute for coffee is the root of chicory (*Chicorium Intybus* L., order *Compositæ*), a native of Europe, where it is also extensively cultivated. The tap root is spindle-shaped, sparingly branched, while fresh, fleshy with a milky juice, after drying, shriveled, hard, horny, on the outer surface brown, and often spirally wrinkled.

Cross sections examined under a lens show the radiating phloem groups, the xylem elements with broad lumens, and the narrow radiating medullary rays.

The reserve material is largely in the form of inulin.

HISTOLOGY.

1. *The Cork* (Fig. 340) tissue consists of a few layers of rather flat cells, with thin brown walls. In surface view they are often ill-defined.

2. *Cortex* (Fig. 341). The parenchymatous ground tissue contains numerous branching and anastomosing latex tubes (*sch*) 6–10 μ broad, with granular contents, which are especially conspicuous after staining. Inulin occurs in the parenchyma, but being soluble in water, is evident only in mounts of alcohol material, in which it forms sphæro-crystals.

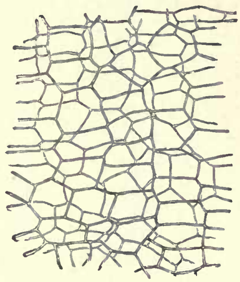

FIG. 340. Chicory (*Chicorium Intybus*). Cork tissue of root in surface view. ×160. (MOELLER.)

3. *Bast* (Fig. 341). The sieve tubes (*s*) are distinguished from the latex tubes by their occurrence in bundles, the absence of branches, and the callus of the sieve plates. Neither the cortex nor the bast contains any sclerenchyma elements whatever.

4. *Wood* (Fig. 342). The most conspicuous elements of the root are the vessels (*g*) made up of short (usually less than 200 μ), moderately broad (usually 20–50 μ) members, with diagonal, porous or non-porous cross walls. The side walls are characterized by numerous moderately elongated transverse pores. Usually the vessels are in radial rows or in groups, seldom isolated. Fuchsin stains them an intense red.

Of less diagnostic value are the thickly porous parenchyma cells and the rather thin-walled wood fibers (*l*), with diagonal clefts. The narrow medullary rays consist of one or two (rarely three) rows of cells.

DIAGNOSIS.

Chicory as used in coffee is in irregular, soft, deep brown grains, with a sweetish taste. It sinks in water, imparting to it a yellow-brown coloration. The important elements are the vessels (Fig. 342, *g*) consisting of short joints, with moderately elongated, transversely arranged pores, and the branching latex tubes (Fig. 341, *sch*) with granular contents. In some fragments one finds numerous vessels, in others numerous latex tubes in a mass of brown parenchyma.

Common adulterants are the roots of dandelion, carrot, beet, and turnip, as well as cereal matter. Dandelion (p. 441) and carrot (p. 418) are distinguished by the elongated narrow pores of the vessels. The

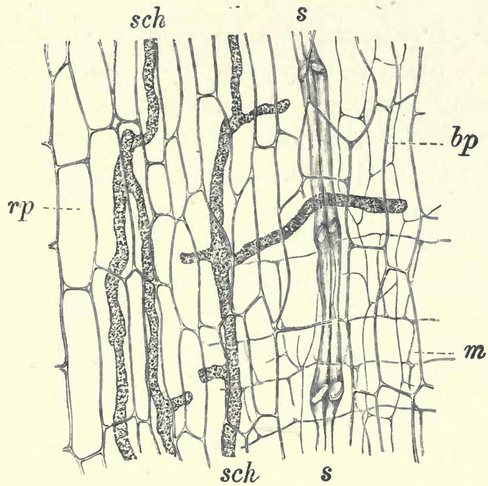

FIG. 341. Chicory. Bark of root in radial section. *rp* cortex parenchyma; *sch* latex tubes; *s* sieve tube; *bp* bast parenchyma; *m* medullary rays. ×160. (MOELLER.)

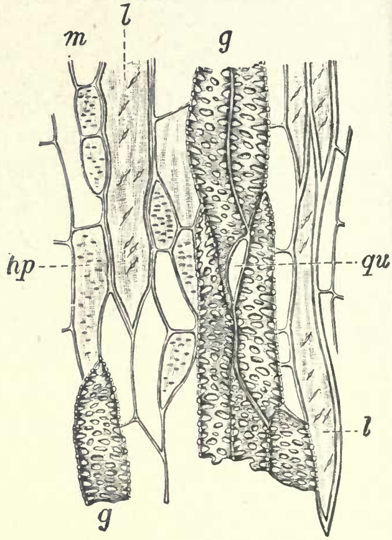

FIG. 342. Chicory. Wood of root in tangential section. *g* pitted vessels with *qu* perforation; *hp* wood parenchyma; *l* wood fibers; *m* medullary ray. ×160. (MOELLER.)

former root, like chicory, contains latex tubes. The vessels of the white turnip (p. 419) have pores similar to those of chicory; latex tubes, however, are lacking. Unusually broad meshes characterize the vessels of the beet (p. 417).

BIBLIOGRAPHY.

See General Bibliography, pp. 671-674: Greenish (14); Hanausek, T. F. (10, 16); Hassall (19); Leach (25); Macé (26); Moeller (29); Planchon et Collin (34); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (14, 45).

See also Bibliography of Coffee, pp. 436–438.

DANDELION.

The root of the common dandelion (*Leontodon Taraxacum* L., order *Compositæ*) is often mixed with chicory. It is thicker and more branched than the latter, and has a more even fracture. The bark is white, with delicate concentric rings; the wood yellow, without rays.

HISTOLOGY.

The bark elements (Fig. 343) are practically the same as those of chicory. The concentric rings are only evident in cross section.

More characteristic is the structure of the wood (Fig. 344). The vessels (*g*) are irregularly distributed, not separated by the medullary rays into distinct groups. They are somewhat broader (up to 80 μ) than those of chicory, and have much longer pores, resembling those of scalariform vessels. Less noteworthy is the absence of wood fibers, as these are not easily found in chicory. The reserve material exists largely as inulin, which in alcohol material forms sphæro-crystals.

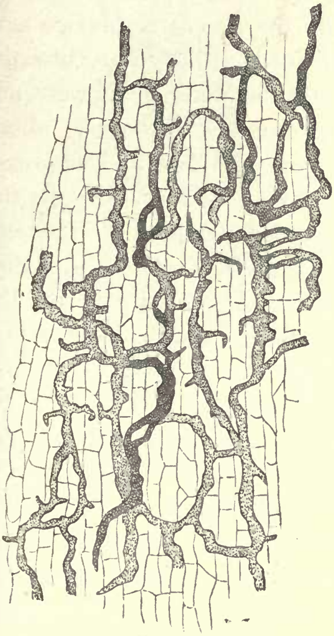

FIG. 343. Dandelion (*Leontodon Taraxacum*). Bark of root in longitudinal section showing latex tubes. (TSCHIRCH.)

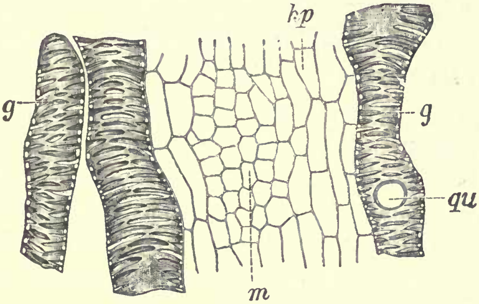

FIG. 344. Dandelion. Wood of root in longitudinal section. *g* reticulated vessels with *qu* perforation; *hp* wood parenchyma; *m* medullary ray. ×160. (MOELLER.)

DIAGNOSIS.

The greater length of the pores in the vessels (Fig. 344 *g*) serves to distinguish this root from chicory. Latex tubes (Fig. 343) are present in both roots.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Moeller (29, 32); Planchon et Collin (34); Tschirch u. Oesterle (40); Vogl (44, 45).

COCOA BEAN.

Chocolate and Cocoa are products of the "beans" or seeds of several small trees, natives of tropical America, of which *Theobroma Cacao* L. (order *Sterculiaceæ*) is by far the most important. The value of cocoa beans was known to the aborigines, especially the Aztecs of Mexico and Peru, who prepared from them beverages and foods. They were brought to the notice of Europeans by Cortez and other explorers, but were not extensively imported into Europe until the seventeenth century, about the time tea and coffee were introduced from the East. *Theobroma* (food of the Gods), the generic name assigned by Linnaeus, suggests the high esteem with which people in his day regarded the seed. At present the world's supply comes chiefly from Venezuela, Guiana, Ecuador, Brazil, Trinidad, Cuba, Mexico, and other regions bordering on the Gulf of Mexico, being gathered in these regions from both wild and cultivated trees, and also to some extent from Java, Ceylon, Africa and other parts of the Old World, where the tree has been successfully cultivated. Cocoa trees with their large dark-green leaves and clusters of fragrant red blossoms are among the most beautiful objects of the Tropics, and the fruit, borne on the trunk and old wood of the tree, is a never ending source of wonder to travelers.

The yellow or brown cocoa fruit is from 12–18 cm. long, from 5–9 cm. wide, and has 10 ridges passing from the base to the apex, giving the surface a melon-like appearance (Fig. 345, *I* and *II*). It contains from 35 to 75 seeds in 5 rows, embedded in a mucilaginous substance.

The seeds after being removed from the fruit are dried at once in some localities, but the better grades are first subjected to a fermentation process, which destroys certain bitter and acrid constituents.

Cocoa beans (Fig. 345, *III–VI*) as found on the market consist of the anatropous seeds, often with more or less of the pulpy inner pericarp adhering. They are irregularly ellipsoidal, 15–30 mm. long, somewhat flattened, and vary from reddish brown to dark brown in color. The hilum at the broader end and the chalaza at the narrower end are connected by the raphe, which runs along one of the narrow sides and divides into numerous branches at the chalaza. The so-called "shell," consisting of spermoderm with portions of the inner pericarp adhering to the outer surface and the perisperm to the inner surface, is thin and brittle, readily breaking away from the cotyledons. There is no endosperm, the reserve material being entirely in the chocolate-colored embryo consisting of two thick and curiously folded cotyledons and a hard radicle about one-third the length of the seed situated at the hilum end. On crushing the seed the radicle separates and the cotyledons break into

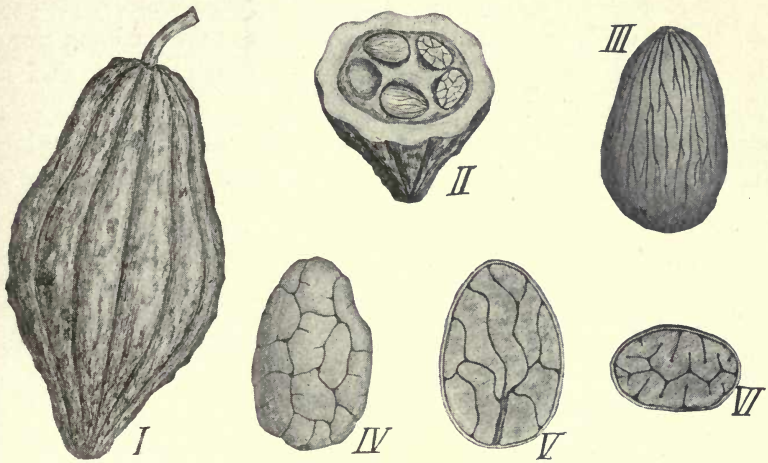

FIG. 345. Cocoa (*Theobroma Cacao*). *I* entire fruit, ×¼; *II* fruit in cross section. *III* seed (cocoa bean), natural size; *IV* seed deprived of spermoderm; *V* seed in longitudinal section, showing radicle (germ); *VI* seed in cross section. (WINTON.)

angular pieces known as cocoa nibs, from which are prepared the chocolate and cocoa of commerce.

Over 50 per cent of the dry embryo consists of fat, the remaining constituents being starch, proteids, theobromin, caffein, a tannin substance known as cocoa red, and other substances in smaller amount.

HISTOLOGY.

Cocoa beans, obtainable from any manufacturer of cocoa products, are suitable for microscopic study. Transverse sections are conveniently cut dry, depending on subsequent treatment with reagents to swell out the tissues. If sections of the shell are soaked for a few minutes in Javelle water, the collapsed cells, particularly those of the endocarp and the outer epidermis of the spermoderm, assume their normal form and the tissues, after washing in dilute acetic acid, are suitably cleared for staining with safranin or some other dye. Sections of the cotyledons are first freed from fat by a suitable solvent and afterwards mounted either in glycerine or water.

Pericarp. Adhering to the surface of most grades of beans is a thin coat consisting of the cells of the inner layers of the mesocarp or fruit pulp and the endocarp.

1. *Mesocarp* (Fig. 346, *mes*). The cells are elongated, often branching, with large intercellular spaces. On soaking in water they become slimy and, together with the endocarp, separate easily from the spermoderm.

2. *The Endocarp* (Figs. 346 and 347, *end*) is made up of narrow elongated cells running transversely or diagonally about the seed and forming the so-called cross-cell layer. These cells are about 15 μ wide and often reach a length of 200–300 μ.

Spermoderm. 1. *The Outer Epidermis* (Figs. 346 and 347, *ep*), consisting of longitudinally elongated, polygonal cells (30–50 μ broad and

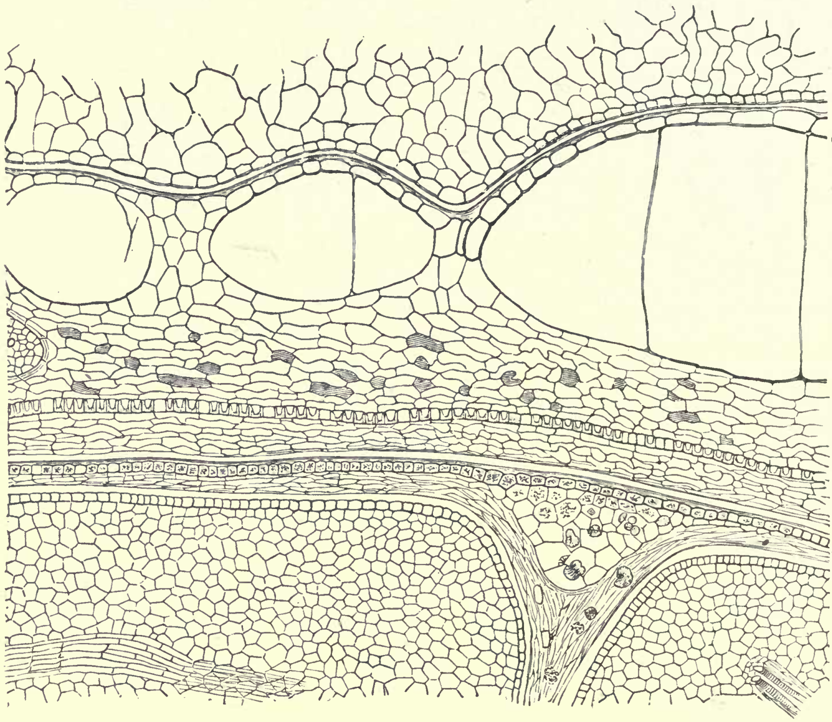

FIG. 346. Cocoa. Cross section of outer portion of bean. *mes* inner layers of mesocarp; *end* endocarp; spermoderm consists of *ep* outer epidermis, *muc* mucilage cells, *p* spongy parenchyma, *st* stone cells and *lp* nutritive layer; *N* perisperm consists of epidermal and obliterated layers; *C* cotyledon. (TSCHIRCH.)

up to 200 μ long), is clearly seen in surface preparations, underlying the cross cells of the endocarp. Owing to their collapsed condition, this layer is not distinct in sections mounted in water, but on treatment with Javelle water, the cells swell to their natural size and the thick cuticle becomes evident.

2. *Mucilage Cells* (Fig. 346, *muc*) underlie the epidermis, forming what at first sight appears to be a broad hyaline coat. They do not, however, form a continuous coat, but a series of pockets separated by tissues of the third layer. Safranin stains the layer in cross section a clear rose color and makes the radial walls more distinct.

3. *Spongy Parenchyma* (*p*). Numerous layers of spongy parenchyma cells, through which pass the bundles of the raphe and its branches, form the third coat. Narrow spiral vessels readily separating from the other elements, characterize the bundles.

4. *Stone Cells* (Fig. 346, *st*; Fig. 349, *d*). The cells of the next layer are thickened on the inner and radial walls. In surface view they are polygonal, often elongated, varying up to 25 μ long. The double walls are about 5 μ thick. Here and there groups of these cells are not thick-

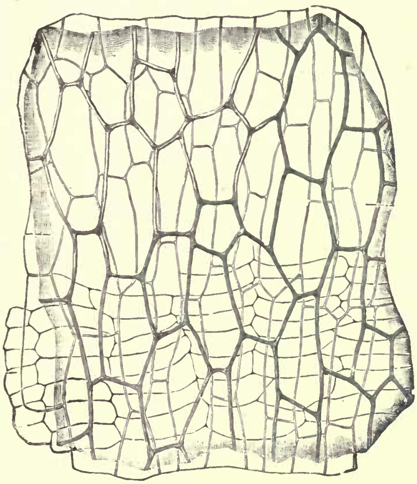

FIG. 347. Cocoa. Outer elements of shell. *ep* epidermis of spermoderm; *end* endocarp (cross cells); *p* parenchyma of mesocarp. ×160. (MOELLER.)

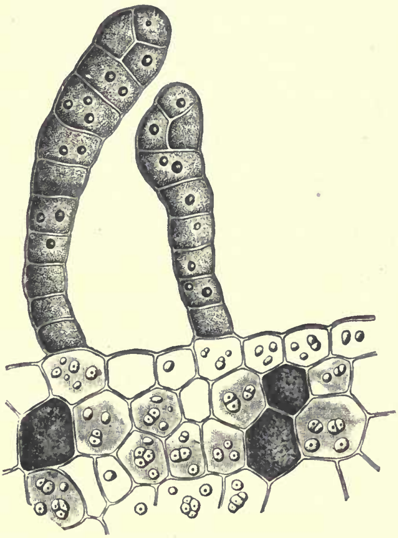

FIG. 348. Cocoa. Cross section of outer portion of cotyledon, showing hairs (Mitscherlichian bodies) and starch parenchyma. (MOELLER.)

ened at all, permitting, according to Tschirch and Oesterle, an exchange of cell liquids.

5. *Nutritive Layer* (Fig. 346, *lp*). Several rows of cells of this layer contain in earlier stages of development cell-contents which later are employed in building up the seed, leaving at maturity only obliterated tissues.

6. *The Inner Epidermis* is indistinct.

Perisperm. (Fig. 346, *N*). The "silver" coat, formerly regarded as endosperm but later shown by Tschirch and Oesterle to be perisperm, envelops the seed and penetrates between the folds of the cotyledons.

1. *Epidermis* A single layer of polygonal cells (15–30 μ) with distinct walls (double walls 3 μ) forms a coat similar to the aleurone cells of many seeds. The cell contents are yellow or white and consist of fatty matter in aggregates, and protein. This layer does not penetrate between the cotyledons.

2. *Obliterated Cells* comprise the remainder of the perisperm. They contain fat in numerous large blade-shaped crystals, often in fan-like clusters, and also dense sphero-aggregates.

Embryo. The bulk of the seed consists of the fleshy cotyledons containing over half their dry weight of fat.

1. *The Epidermis* (Figs. 348 and 349) is made up of polygonal cells and remarkable several-celled hairs (*tr*) named in honor of their discoverer "Mitscherlichian bodies." These latter consist of a single row of cells near the base, but expand at the outer end into a club-shaped body often several cells broad. Vogl has rightly observed that these hairs occur less often on the surface of the cotyledon adjoining the perisperm than in the folds, and Tschirch and Oesterle, that they are still more abundant on the radicle. The perisperm, particularly that portion within the folds of the cotyledons, often has these hairs adhering to its inner surface. Both the hairs and the other epidermal cells contain small brown bodies, which, according to Vogl, are colored blood-red by chloral, olive-brown by ferric chloride, and bright yellow by ammonia, the latter reagent also causing the grains to swell. These reactions are not always decisive.

2. *Ground Tissue* (Fig. 348). The cells in the interior of the cotyledons either contain starch and aleurone grains embedded in fat, or a pigment varying from violet to brown in color. Fat, the chief constituent of the embryo, occurs either in rosettes of needle-shaped crystals or in compact masses. Starch is present in amounts varying up to 10 per cent, the rounded grains (4–12 μ), each with a distinct hilum, resembling closely those of allspice and cinnamon. The grains occur singly, in pairs, or in triplets. They stain slowly with iodine, even after the removal of the fat. The aleurone grains are usually smaller than the starch grains and contain several globoids, but larger grains with crystalloids are also found here and there. Both the starch and aleurone grains, the latter being the less abundant, are clearly differentiated by extracting

sections with ether and mounting in chlorzinc iodine. Scattered among these cells are the pigment cells containing a substance varying from violet to brown in color known as cocoa red, which, together with theobromin, caffein and dextrose, is formed by the action of an enzyme on a glucoside originally present in the bean. Usually this substance becomes blood-red with concentrated sulphuric acid, gray-blue with ammonia, greenish-yellow with caustic soda, and olive with ferric chloride, although the color reactions vary greatly in different samples, owing

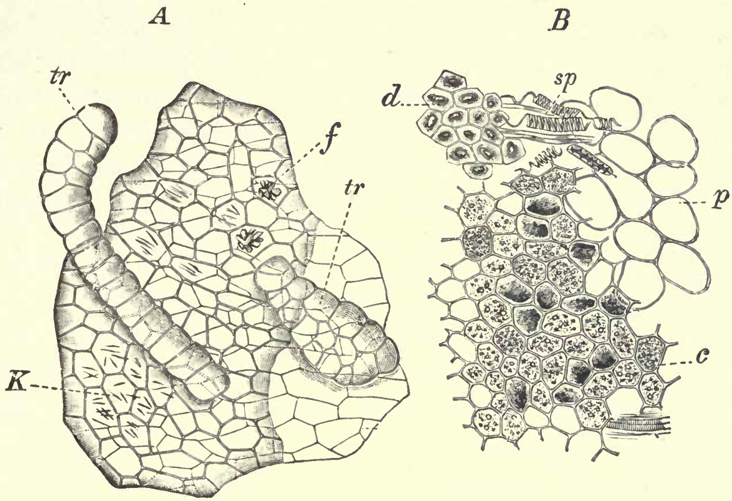

FIG. 349. Cocoa. *A* perisperm (silver coat) consisting of epidermis and parenchyma: *K* and *f* crystals; *tr* adhering hairs (Mitscherlichian bodies) from epidermis of cotyledon. *B* elements of cocoa powder, showing *c* cotyledon tissues with fat cells and pigment cells, also *p* parenchyma, *sp* spiral vessels and *d* stone cell layer of shell (spermoderm). ×160. (MOELLER.)

possibly to lack of uniformity in the process of fermentation, roasting, etc. Tschirch and Oesterle describe methods for separating theobromin gold chloride and theobromin silver nitrate, but these, although of scientific interest, are of little value in diagnosis. Caffein also occurs in small amounts in the embryo, but its presence is best demonstrated by purely chemical means.

DIAGNOSIS.

Plain Chocolate. The first stages in the manufacture of both chocolate and cocoa are the same.

After removing stones, chips and other impurities, the beans are roasted, thus developing a desirable flavor and facilitating the processes of separation from the shells and grinding. The beans are then crushed by machinery and separated from the shells. In some factories the hard "germs" (radicles) are also removed.

The broken cotyledons, free from shells, known as "cocoa nibs," are next ground in the chocolate mill. The heat of grinding melts the fat which makes up about half the weight of the nibs, and the ground product runs out of the mill as a thin paste. This paste, after cooling in moulds, is plain or unsweetened chocolate, also known as cocoa mass.

The most characteristic tissues of the embryo are the multi-cellular bodies of the epidermis (Fig. 349), but these are not numerous and are largely destroyed in grinding. Of chief value in identification are the starch grains (Fig. 348), which, although much like the grains of allspice and cinnamon, do not resemble those of any common adulterant. The violet or brown contents of the pigment cells are also of some diagnostic importance, though the reactions are often misleading. Tissues of the spermoderm (Fig. 347) are exceedingly rare in cocoa products made from carefully shelled beans. Among the adulterants with definite microscopic characters found in plain chocolate are wheat flour, maize starch, peanut meal, peas, acorns, arrowroot, and cocoa shells. Other adulterants which can be identified only by chemical and physical methods are foreign fats, mineral make-weights, iron salts, various pigments, and coal-tar dyes.

Sweet Chocolate is prepared by mixing pulverized sugar and flavors with the warm chocolate paste before moulding. Vanilla beans (or artificial vanillin) and cinnamon are most commonly employed as flavoring materials, less often cloves, nutmegs, mace, cardamoms, and Peru balsam. The adulterants are those noted under plain chocolate.

Cocoa is obtained by removing a portion of the fat (cocoa butter), from warm cocoa mass by pressure and reducing the residue to a powder, with or without addition of vanilla flavor.

Dutch Process, or "Soluble" *Cocoa*, is cocoa treated with an alkali, usually soda or ammonia, to hinder the fat from collecting on the surface of the beverage prepared from it. The microscopic elements are not altered by this treatment. Various starchy preparations and oil-seed products such as are noted under chocolate are used as adulterants.

Cocoa Shells, obtained in large quantities in the manufacture of chocolate and cocoa, are used to some extent in the preparation of a beverage, for the manufacture of theobromin, and in mixed cattle foods, but are most commonly added to cocoa products or spices as an adulterant.

The striking histological elements are the cross cells or inner epidermis (Fig. 347, *end*) of the pericarp, and the underlying tissues of the spermoderm, especially the outer epidermis (*ep*), the numerous narrow spiral vessels of the bundles, and the stone cells. The shells contain a higher percentage of crude fiber than the cotyledons, but much less fat, starch, and theobromin.

Compound Cocoa Products. Zipperer gives formulas or analyses of seventy-four preparations of chocolate or cocoa with other materials. He states, however, that this list is not complete and does not contain any of the medicinal chocolates. Some of the ingredients named are oatmeal, barley meal, malt, malt extract, wheat flour, potato flour, rice peas, peanuts, acorns, cola nuts, sago, arrowroot, Iceland moss, gum Arabic, salep, dried meat, meat extract, peptones, milk powder, plasmon (casein), eggs, saccharin, vanilla, various spices, and inorganic salts. Of the products named, only those of vegetable origin can usually be identified under the microscope.

Malt Chocolate and Malt Cocoa more often contain malt extract than ground malt, only the latter being distinguishable under the microscope.

Milk Chocolate, a popular mixture of sweet chocolate and milk powder, has no distinctive microscopic characters but "Plasmon Chocolate," "Plasmon Cocoa" and various similar preparations show under the microscope flakes of ceasin (Plasmon), which may be tested with reagents and dyes.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Blyth (5); Flückiger (11); Greenish (14); Hanausek, T. F. (16, 48); Hassall (19); Leach (25); Macé (26); Meyer, A. (28); Moeller (29, 30, 31, 32); Planchon et Collin (34); Schimper (37); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (43, 45); Weigmann (10).

BASTINGS: Starch Grains in the Different Commercial Varieties of Cocoa Beans. Amer. Journ. Pharm. 1894, **66**, 369.

BECKURTS und HARTWICH: Beiträge zur chemischen und pharmakognostischen Kentniss der Cacaobohnen. Arch. Pharm. 1890, **230**, 589.

BERNHARD: Ueber Cacao und dessen Präparate. Chem. Ztg. 1888, **12**, 445. 1889, **13**, 32.

BERNHARD: Ueber die Untersuchung von Cacao und Chocolade. Vers. Schw. Chem. 12. April, 1890.

BEYTHIEN: Casseler Haferkakao. Jahresber. chem. Unters.-Amt. Dresden, 1900, 10.

BEYTHIEN und HEMPEL: Chokoladenmehle. Ztschr. Unters. Nahr.-Genussm. 1901, **4**, 23.

COSTER, HOORN und MAZURE: Falsifications observées en Holland. Rev. internat. falsificat. 1887–88, **1**, 161.

ELSNER: Rep. analyt. Chem. 1884, 370; 1885, **5**, 128, 211.

FILSINGER: Die Untersuchung der Kakaofabrikate auf Gehalt an Kakaoschalen. Ztschr. öffentl. Chem. 1899, **5**, 27.

FISCHER und GRÜNHAGEN: Untersuchung des Kakao und der Chokolade auf Kakaoschalen. Jahresber. chem. Unters.-Amt. Breslau, 1899–1900, 34.

FISCHER: Nachweis von Kakaoschalen. Jahresber. chem. Unters-Amt. Breslau, 1901–02, 27.

HAGER: Ueber Eichelkakao und Chokolade. Pharm. Ztg. 1888, **33**, 511.

HANAUSEK, T. F.: Mikroskopische Untersuchung eines holländischen Eichelcacaos. Ztschr. Nahr.-Unters. Hyg. 1887, **1**, 247.

HANAUSEK, T. F.: Beiträge zur Histochemie der Cacaosamen. Apoth.-Ztg. 1894, 145.

HARTWICH: Ueber die Pigmentzellen des Cacaosamens. Arch. Pharm. 1887, **25**, 958.

HARTWICH: Zur Nachweisung fremder Stärkemehle in der Chokolade. Chem. Ztg. 1888, **12**, 375.

LAGERHEIM: Nachweis von Kakaoschalen. Svensk Kemisk Tidskrift, 1901.

LAGERHEIM: Om den mikroskopiska undersökningen af kakao och chokolad. Svensk Farmaceutisk Tidskrift 1902, No. 9.

LEGLER: Cellulosegehaltes der Kakaobohnen. Rep. analyt. Chem. 1884, **4**, 345.

LEGLER: Zur mikroskopischen Untersuchung der Cacaobohnen. 14–17 Jahresber. Chem. Centralstelle. Dresden, 1886–88.

MANSFELD: Kakao-Ersatzmittel. Jahresber. Unters. allg. österr. Apoth.-Ver. 1901–02, **14**, 5.

MICHAELIS: Eichelkakao, Eichelchokolade. Pharm. Ztg. 1888, **33**, 568.

MITSCHERLICH: Der Cacao und Die Chocolade. Berlin, 1859.

NOTHNAGEL: Untersuchung von Getreide-Kakao. Apoth.-Ztg. 1900, **15**, 181.

PAYEN: Action de l'iode sur l'amidon du cacao. Jour. pharm. chim. 1862, **41**, 367.

PENNETIER: Recherche de la farines de blé dans le chocolat. Jour. pharm. chim. 1887, **15**, 141.

PFISTER: Eine neue Chokoladenfälschung. Forschber. Lebensm. Hyg. Pharmkgn. 1894, **1**, 543.

SPÄTH: Verfälschung von Cacao. Forschber. Lebensm. Hyg. 1894, **1**, 344.

THIEL: Zur Histologie und Physiologie der Kakaosamen. Forschber. Lebensm. Hyg. 1894, **1**, 219.

TICHOMIROW: Ueber die Cacaocultur auf Ceylon. Pharm. Ztschr. f. Russl. 1892, **31**, 260.

TROJANOWSKY: Beitr. z. pharmakogn. u. chem. Kenntniss des Cacaos. Inaug.-Diss. Dorpat, 1875.

TSCHIRCH: Untersuchungen der Eichel-Cacaosorten des Handels. Pharm. Ztg. 1886, **32**, 190.

TSCHIRCH: Ueber den anatomischen Bau des Cacaosamens. Arch. Pharm. 1887, **25**, 605.

TSCHIRCH: Entwicklungsgeschichtliche Studien. Schw. Woch. Chem. Pharm. 1897, **35**, No. 17.

WELMANS: Zur Untersuchung der Kakaofabrikate auf ihren Gehalt an Kakaoschalen. Ztschr. öffentl. Chem. 1899, **5**, 479.

ZIPPERER: Ueber den Werth der mikroskopischen Untersuchung bei Bestimmung fremden Stärkemehls in Chokolade. Chem. Ztg. 1888, **12**, 26.

ZIPPERER: Beiträge zur Mikrochemie des Thees und des Cacao. VII. Vers. d. freien Vereinig. bayr. Chem. Speyer, 1888.

GUARANA.

The seed of *Paullinia sorbilis* Mart. (order *Sapindaceæ*), like coffee and the kola nut, contains caffein, and is used in Brazil as a stimulant. The dried paste in the form of dark brown, sausage-like cylinders, is used in medicine.

HISTOLOGY.

The epidermis (Fig. 350) of the spermoderm consists of characteristic palisade cells with thick walls. The embryo (Fig. 351) contains small starch grains of the allspice type.

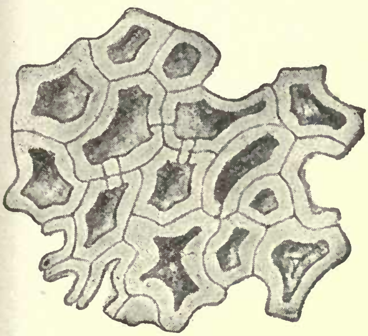

FIG. 350. Guarana (*Paullinia sorbilis*). Palisade epidermis of spermoderm in surface view. (MOELLER.)

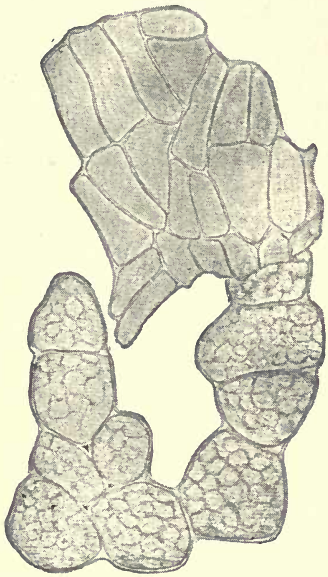

FIG. 351. Guarana. Epidermis and parenchyma of cotyledon. (MOELLER.)

DIAGNOSIS.

In the commercial product the starch grains are more or less distorted, owing to the heat employed in drying. Although made from the shelled seeds, fragments of the palisade cells are always present.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Moeller (32); Vogl (45).

KOLA NUT.

The seeds of *Cola acuminata* R. Br. have long been used by the natives of West Africa as a stimulant, and have also been introduced into other countries as a drug. They contain both caffein and theobromin. The commercial product consists of the dried cotyledons, which resemble somewhat those of a Spanish chestnut, except that they are of a dark-brown color.

The starch grains are ovate or reniform, up to 30 μ long, and have an elongated hilum. They are quite like the starch grains of legumes.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Vogl (45).

TEA.

Tea is the leaf of a shrub (*Camellia Thea* Link, order *Ternstrœmiaceæ*), which since time immemorial has been extensively cultivated in China and Japan, also more recently in India (Assam), Ceylon, and Java. Its culture in South Carolina, although still in the experimental stage, bids fair to become an important industry.

The numerous kinds of tea owe their difference in excellence and trade value to differences in the mother plant on the one hand, and to the degree of ripeness and method of preparation on the other. As a rule only the leaf buds and the youngest leaves, not the flowers, are gathered. What are known in commerce as "flowers" are the gray, silky-hairy leaf buds.

Black and green tea owe their peculiar characters to the method of preparation. In the first the chlorophyl is destroyed, in the latter more or less preserved.

Brick tea consists of large leaves not suitable for the preparation of black and green tea, ends of branches and other refuse, compressed into blocks. It is consumed almost entirely by the Asiatic nomads.

In China tea designed for export is often perfumed by mixing with it fragrant flowers (of *Aurantiaceæ*, *Osmanthus fragrans*, *Jasminum*, *Aglaja odorata*, *Gardenia florida*, *Chloranthus inconspicuus*), which are removed after they have wilted. The bottom of the chest is sometimes covered with flowers.

Tea leaves vary more than is commonly stated. They are narrow or half as broad as long, pointed or nearly spatulate, serrate or nearly entire, entirely smooth or hairy on the under side, more or less leathery. Grown to full maturity they often reach 10 cm., rarely 15 cm., in length, but as picked for the market they range from the length of the little finger down to the tiny leaves of the buds.

The following characters are common to all tea leaves: the firm, rather thick texture; the glossy upper surface; the short stem into which

FIG. 352. Tea (*Camellia Thea*). Leaf, natural size. (MOELLER.)

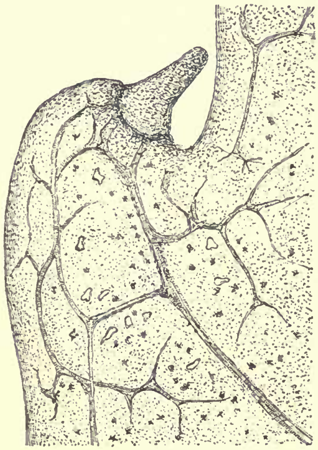

FIG. 353. Tea. Fragment of leaf treated with chloral hydrate, showing tooth, veins, crystal rosettes, and stone cells. Somewhat enlarged. (SCHIMPER.)

the base of the leaf tapers; the thick margins, rolled a little towards the inner surface, with cartilaginous teeth; the veins which branch from the midrib at angles usually greater than 45°, and at some distance from the margin form loops uniting adjoining ribs (Fig. 352). The teeth (Fig. 353) on the margin of the leaf are shrunken multicellular glands which break off readily from old leaves.

Tea fruit (Fig. 354), consisting of the pericarp with calyx and peduncle attached, resembles cloves. The pericarp is globular or triangular, and has three cells, each containing a single seed.

HISTOLOGY.

Microscopic mounts are prepared after soaking or boiling with water.

The Upper Epidermis (Fig. 355) consists of small (50 μ) cells with slightly wavy walls, without stomata or hairs.

Mesophyl (Fig. 357). The chlorophyl parenchyma adjoining the upper epidermis is made up of palisade cells which in surface view are circular in outline (Fig. 355, *p*); that adjoining the lower epidermis is

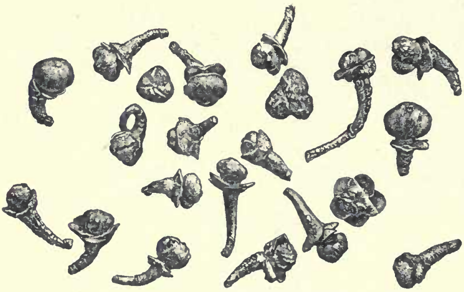

FIG. 354. Tea Fruit. Natural size. (WINTON.)

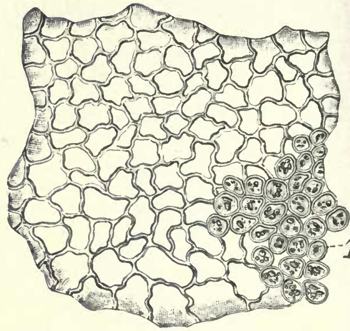

FIG. 355. Tea. Upper epidermis of leaf and *p* group of palisade cells, seen from below. ×160. (MOELLER.)

spongy, with large star-shaped branching cells (Fig. 356, *m*). Large colorless stone cells or idioblasts (Fig. 357; Fig. 358, *st*) which are the most characteristic elements of the tea leaf, occur here and there in young leaves and in considerable numbers in mature leaves. They form as it were braces holding apart the epidermal layers. They are extremely

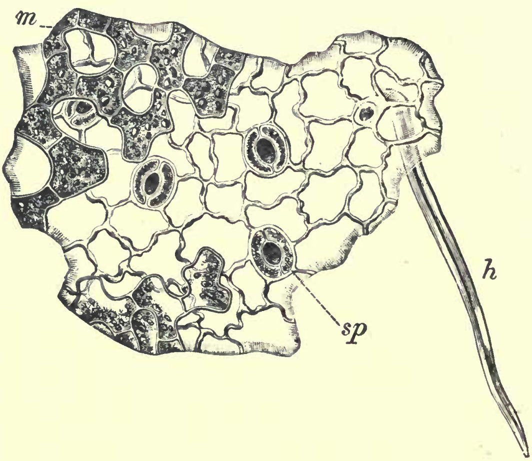

FIG. 356. Tea. Lower epidermis of leaf with *h* hair and *sp* stoma, and *m* spongy parenchyma of mesophyl, seen from below. ×160. (MOELLER.)

variable in form and size, but are usually elongated (up to 150 μ), broadened at the ends, and have simple and forked branches. The thickness of the porous walls often exceeds the breadth of the cavity.

Crystal rosettes occur in considerable numbers.

The Lower Epidermis (Fig. 356) consists of large (70 μ) irregular cells with wavy contour, among which are numerous large (40–60 μ) broadly elliptical stomata surrounded usually by 3–4 accompanying cells.

The hairs found on this epidermis, like the idioblasts, are highly characteristic. On old leaves they occur sparingly or not at all, and their scars, owing to the growth of the neighboring cells, are also seldom

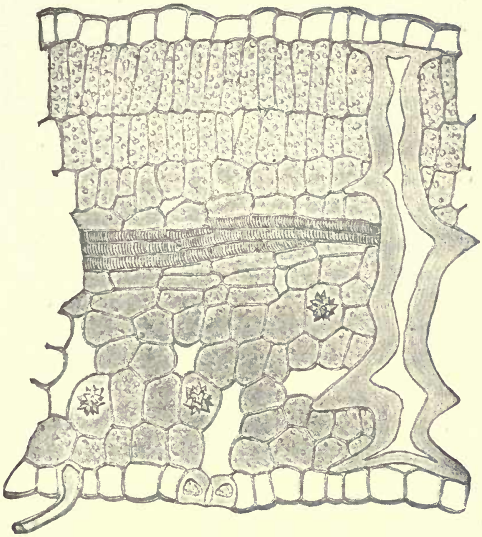

FIG. 357. Tea. Cross section of leaf showing epidermal cells, palisade cells, fibro-vascular bundle, spongy parenchyma with crystal rosettes, and large stone cell. (MEZ.)

evident. On young leaves, however, they form a dense pubescence. They are unicellular, thick-walled, often over 1 mm. long, and are usually geniculate near the base, thus causing them to lie flat on the surface of the leaf.

DIAGNOSIS.

After heating to boiling in water the leaves may be spread out and examined. Even quite small fragments can be recognized by their texture, venation, dentation and other macroscopic characters. The chief microscopic elements of value in diagnosis are the epidermal cells, the geniculate hairs and the idioblasts.

Tea Adulteration. Gross adulteration, such as the addition of exhausted leaves, foreign leaves and mineral make-weights, is seldom practiced at the present time. Low-grade teas often contain tea stems, and sometimes tea fruit. Facing, although objectionable, is not usually regarded as an adulteration.[1]

Exhausted Tea. Leaves which have been used once for the preparation of the beverage are said to be collected in England, Russia, and China, impregnated with catechu or caramel, and prepared in imitation of genuine tea. This worthless product has the same microscopic appearance as genuine tea, but can often be detected by chemical means,

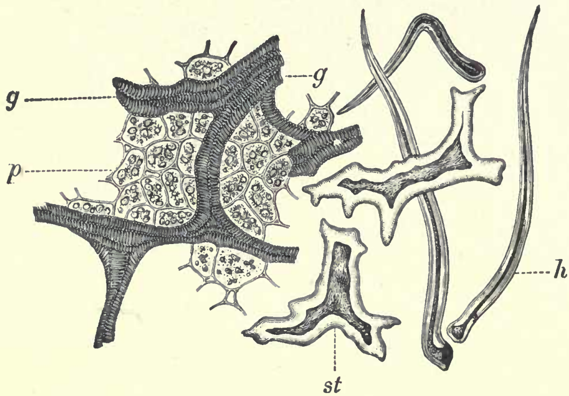

FIG. 358. Tea. Tissues of leaf isolated by warming in alkali and squeezing with cover glass. *g* spiral vessels of nerves; *p* chlorophyl parenchyma; *st* stone cells; *h* hairs. ×160. (MOELLER.)

particularly determinations of hot-water extract, tannin, total and water-soluble ash.

Tea Fruit. Soltsien has reported several cases of adulteration with the dried fruit. Winton found in a sample sold in Connecticut 11.5 per cent of this adulterant.

Tea Stems. Tea often contains a small amount of stems as an accidental impurity. A considerable amount indicates adulteration.

"*Lie Tea*" consists of tea leaves and other refuse made into lumps with starch-paste. These lumps fall apart on soaking in water.

Mineral Make-weights, including soapstone, gypsum, iron dust, and sand, are detected by chemical analysis.

Facing. A large part of the green tea and much of the black tea is "faced," or coated, to impart a gloss and an attractive color. Among the materials employed in facing green tea are Prussian blue (ferric ferro-

[1] Except for facing, the tea on the American market at the present time is seldom adulterated (A. L. W.).

cyanide), indigo, turmeric, soapstone, and gypsum. Black tea is frequently coated with plumbago.

Leach describes simple methods for detecting several of these materials by microscopic examination: Plumbago is evident by its bright glossy appearance; Prussian blue, by the transparent light blue, and indigo by the greenish-blue particles. The color of Prussian blue is discharged by sodium hydroxide, while that of indigo is not. The detached particles of coloring matter often rise to the surface when leaves are shaken in hot water, and may be floated on a slide for microscopic examination. Prussian blue may be chemically detected in the sediment as above obtained by dissolving in hot alkali, acidifying with hydrochloric acid and then adding ferric chloride. A blue color is indicative of the ferric ferrocyanide.

Foreign Leaves, widely different in form and size from the tea leaf, can be used as adulterants provided they are not too hairy or too strongly scented. The adulterator selects not only leaves which outwardly resemble tea leaves, of which there are an abundance, but, trusting to the indifference of the consumer, uses leaves of the oak, poplar, maple, plane tree, and others, which do not have the slightest resemblance to tea leaves, and which the layman, if he would take the trouble to spread out the spent leaves, would at once either identify, or at least recognize as foreign. Most of these leaves on close inspection show peculiarities in texture, venation, dentation, and other characters, thus rendering microscopic examination superfluous. Only in cases where absolute proof is required, especially when the leaves are in fragments, is it necessary to resort to microscopic examination. The leaves described on pp. 458–483 do not include all that may be used as adulterants of tea, but only those which resemble tea leaves in form or else are most commonly used either as adulterants or substitutes.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Bell (1); Berg (3); Blyth (5); Greenish (14); Hanausek, T. F. (10, 16); Hassall (19); Leach (25); Macé (26); Moeller (29, 30, 31, 32); Planchon et Collin (34); Schimper (37); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (43, 45).

ANONYMOUS: Teefälschung in Russland. Schw. Woch. Chem. Pharm. 1892, 142.
Weidenröschenblätter als Tee. Pharm. Ztg. Russland, 1875.

BATALIN: Ein neues Ersatzmittel für Tee. Indbltt. 1888, **25**, No. 14, 59.

BORKOWSKI: Du faux thé russe. Rev. int. falsific. 1896, **9**, 131.

BRUNOTTE: De la détermination histologique des falsifications du Thé. Thèse Éc. de Ph. de Nancy, 1883.

COLLIN: Du thé chinois et de quelques-une de ses succédanés. Journ. pharm. chim. 1900, **11**, 15.
DRAGENDORFF: Fälschungen in Russland. P. Tr. (3), 1048.
HANAUSEK, T. F.: Ueber den kaukasischen Tee, nebst Beiträgen zur vergleichenden Anatomie der Vacciniumblätter. Chem. Ztg. 1897, **21**, 115.
LORENZ: Tee aus Blättern der kaukasischen Preiselbeere. Apoth. Ztg. 1902, **16**, 694.
LUBELSKI: Ueber Kultur und Fälschungen des Tees. Rep. Fals. intern. **3**, 88.
MEDHURST: Consular Report. Drog. Ztg. **5** u. Jahresber. Fortschr. Pharm. 1879, 43.
MEYER, AD.: Anat. charakt. off. Blätter u. Kräuter. Halle, 1882.
MOLISCH: Histochemie. Jena, 1891.
NETOLITZKY: Dikotyledonblätter. Wien, 1905.
RICHE et COLLIN: Falsification du thé en Chine. Jour. pharm. chim. 1890, **21**, 6.
RICHE: Gefälschter Tee. Chem. Ztg. 1899, **13**, Rep. 19, 155.
SOLTSIEN: Verfälschung des Tees mit Teefrüchten. Pharm. Ztg. 1894, **39**, 347. Ztschr öffentl. Chem. 1902, **8**, 254.
STACKMANN: Kaukasischer Tee aus Kutais. Ztschr. anal. Chem. 1895, **34**, 49.
TICHOMIROW: Zur Frage über die Expertise von gefälschtem und gebrauchtem Tee Pharm. Ztschr. f. Russl. 1890, **29**, No. 29–40.
WINTON: The Adulteration of Tea with Tea Fruit. Conn. Agr. Exp. Stat. Rep. 1901, 183.

GROMWELL LEAVES.

The leaves of gromwell (*Lithospermum officinale* L., order *Borraginaceæ*) are entire, sessile, up to 8 cm. long and scarcely 15 mm. broad (Fig. 359). The veins are few, form sharp angles with the midrib, and near the margins anastomose, forming flattened loops. The leaves have rough hairs on both sides which are evident on passing the fingers from tip to base, and are seen under a lens to spring from rounded humps.

FIG. 359. Gromwell (*Lithospermum officinale*). Leaf, natural size. (MOELLER.)

The Epidermis on the upper side (Fig. 360) consists of irregularly polygonal cells, on the lower side (Fig. 361) of thin-walled cells with more or less wavy contour. The stiff, somewhat curved, sharp-pointed, warty hairs are 600 μ or more long, and are often 40 μ broad at the base. They have thickened walls, and contain cystoliths or concretions of calcium carbonate, which are especially well developed in the retort-shaped bases. Cystoliths are also present in the cells of the upper epidermis. Small stomata, 30 μ long, occur in the upper epidermis in great numbers.

Gromwell leaves prepared like black tea are sold unmixed in

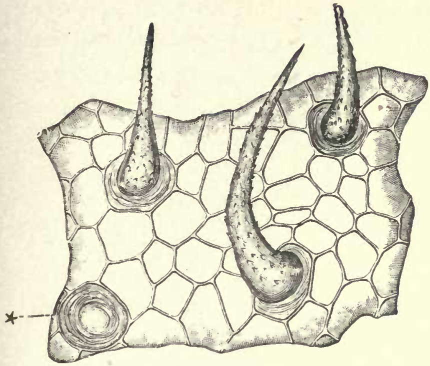

FIG. 360. Gromwell. Upper epidermis of leaf. ×160. (MOELLER.)

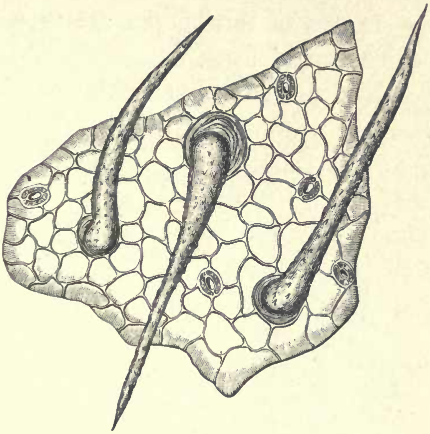

FIG. 361. Gromwell. Lower epidermis of leaf. ×160. (MOELLER.)

Bohemia, and a similar product, containing the fruits as well as the leaves, was at one time made in Styria. The chief characters are the thin texture of the leaf and the rough hairs.

WILLOW HERB LEAVES.

The narrow-leaved willow herb (*Epilobium angustifolium* L., *Chamænerium angustifolium* Scop., order *Oenothereæ*) has lanceolate, sharp-pointed leaves which are sessile or with short petioles, entire or sparingly toothed (Fig. 362). The numerous veins are at nearly right angles to the midrib, and anastomose at the border in short loops.

Upper Epidermis. (Fig. 363.) The cells are about 50 μ broad, with slightly wavy, thick, here and there knotty-thickened walls. Stomata are absent, but water stomata occur near the apex.

Lower Epidermis. (Fig. 364.) The cells have thinner and wavier walls than those of the upper epidermis, and are covered by a wrinkled cuticle with a finely granular deposit of wax. The numerous stomata are about 30 μ long and 20 μ broad. Under each tooth is a water stomata. Young leaves bear along the veins unicellular, blunt, thin-walled, striated, mostly crooked hairs (Fig. 365).

The Mesophyl contains numerous raphides (Fig. 364) accompanying the bundles.

FIG. 362. Willow Herb (*Epilobium angustifolium*). Leaf, natural size. (MOELLER.)

Leaves of this species are used in Russia as a substitute for or an adulterant of tea.

The chief characters are the thin, entire or sparingly toothed leaves with

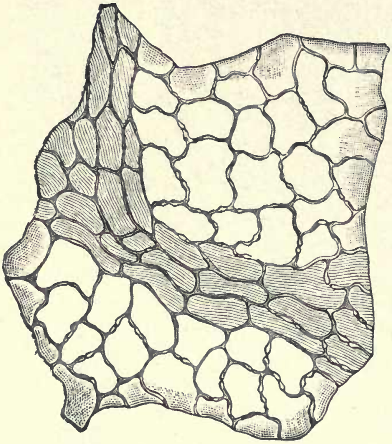

FIG. 363. Willow Herb. Upper epidermis of leaf. × 160. (MOELLER.)

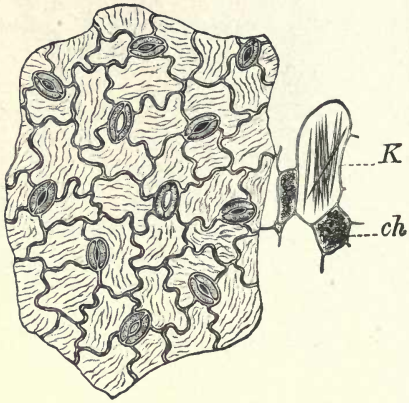

FIG. 364. Willow Herb. Lower epidermis of leaf, also *K* raphides cell and *ch* chlorophyl cells. × 160. (MOELLER.)

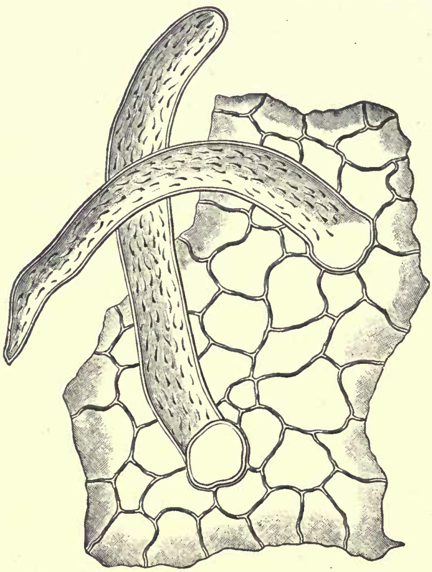

FIG. 365. Willow Herb. Epidermis of young leaf with hairs. (MOELLER.)

numerous veins nearly at right angles to the midrib, the striated lower epidermis with wavy walls and small stomata, and the raphides.

The leaves of the hairy willow herb (*Epilobium hirsutum* L.) are clasping, lanceolate, wavy-toothed, with a smooth upper and a hairy lower surface (Fig. 366). The pronounced branching veins form loops near the margins. The epidermal cells are similar to those of the foregoing

FIG. 366. Hairy Willow Herb (*Epilobium hirsutum*). Leaf, natural size. (MOELLER.)

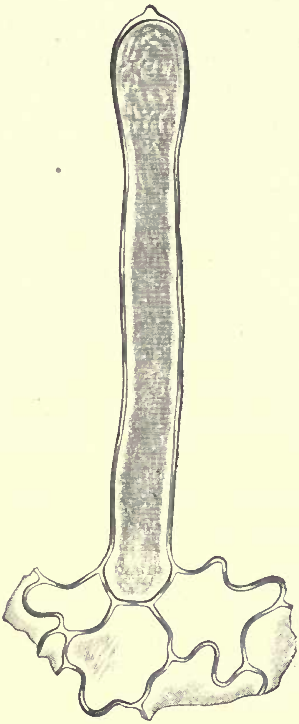

FIG. 367. Hairy Willow Herb. Epidermis of leaf with hair. (MOELLER.)

FIG. 368. Willow (*Salix sp.*). Leaf, natural size. (MOELLER.)

species, but the hairs are smooth, and many of them have characteristic globular heads (Fig. 367). Pointed hairs, much longer than the preceding, are also present, being especially abundant at the margins.

WILLOW LEAVES.

The willows (*Salix*) have long, pointed, entire or toothed, smooth or hairy, short-petioled, rather thick leaves. They resemble tea leaves, but the veins are more numerous, and they do not form loops at the margin (Fig. 368).

The Epidermis (Fig. 369) is much the same on both surfaces, but on the upper surface is strongly cuticularized and striated. The cells are small, sharply polygonal or very slightly sinuous in outline. Numerous small (25 μ) stomata, often with two accompanying cells, occur on the lower epidermis. Both epidermal layers are clothed with hairs, which resemble those of tea, but are not geniculate. The hairs of young leaves

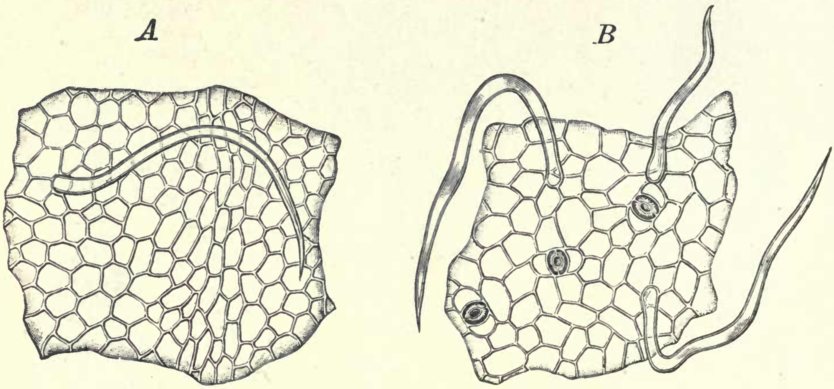

FIG. 369. Willow. *A* upper epidermis of leaf. *B* lower epidermis with hairs and stomata. ×160. (MOELLER.)

are thin-walled, while those of full-grown leaves often have walls so strongly thickened as to obliterate the cavities. The marginal teeth end in multicellular glands.

The Mesophyl contains numerous oxalate rosettes and also simple crystals.

Willow leaves, according to the English consul Medhurst, are collected in China in great quantities, prepared like tea, and mixed with this product to the extent of 20 per cent. (See Bibliography of Tea, p. 458.)

This leaf can usually be distinguished from tea by its venation. The characteristic microscopic elements are the thin-walled hairs and the four-celled stomata. The crystal rosettes of both leaves are similar, but simple crystals are not found in tea.

ASH LEAVES.

The leaflets of the odd-pinnate leaves of the ash (*Fraxinus* sp., order *Oleaceæ*), are similar to tea leaves in general outline, although they are often broader and more sharply toothed, and, furthermore, have very different venation (Fig. 370). The numerous veins, which in young leaves are especially well marked, anastomose near the margin, and from the loops arise short veinlets which usually end in the notches between the teeth.

Epidermis (Fig. 371). On both sides the cells have sinuous walls. The lower epidermis bears numerous large stomata (30–40 μ), without accompanying cells. Highly characteristic are the cuticular thickenings or folds at the poles of the stomata, which give the latter a horned appearance. Glandular hairs with wheel-like multicellular heads, also short one- to two-celled hairs with striated cuticle, occur on the lower epidermis.

Mesocarp crystals are absent.

The indescribable but highly characteristic thin sinuous walls of the upper epidermis, the elongated and horned stomata and the glandular hairs are positive means of distinction from tea.

FIG. 370. Ash (*Fraxinus sp.*). Leaflet, natural size. (MOELLER.)

ROWAN LEAVES.

The European rowan or mountain ash (*Sorbus Aucuparia* L., *Pyrus Aucuparia* Gaertn., order *Rosaceæ*), is often cultivated because of its scarlet berries. The odd-pinnate leaves are pubescent when young, nearly smooth when old (Fig. 372). The leaflets are lanceolate and irregularly serrate. The veins pass into the teeth without forming loops.

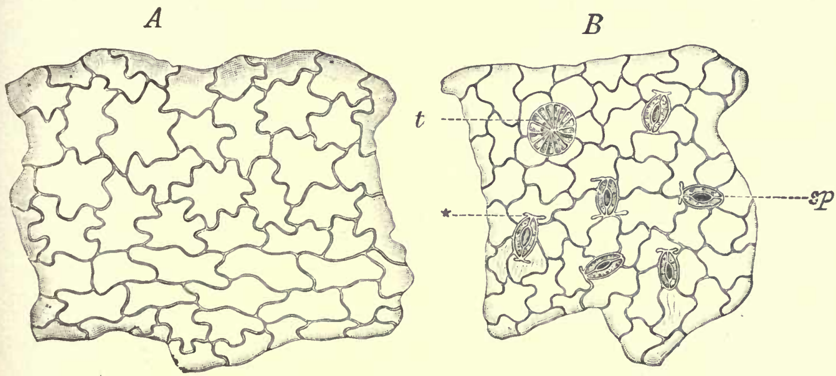

FIG. 371. Ash. *A* upper epidermis of leaf. *B* lower epidermis with *sp* stomata and *t* glandular hair. ×160. (MOELLER.)

The Epidermis (Fig. 373) of the under side is like that of the upper side except that stomata are present. In outline the cells are partly polygonal, partly sinuous. Delicate striations mark the cuticle. The long, unicellular, sinuous hairs with rounded bases are characteristic.

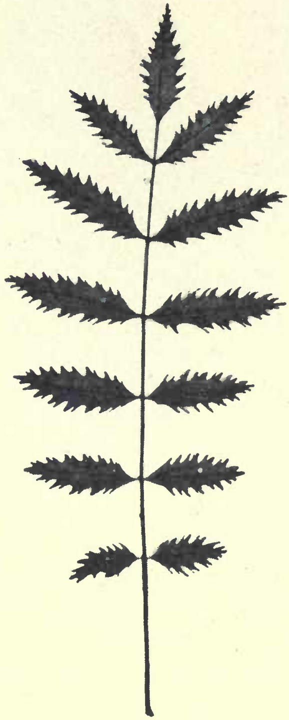

FIG. 372. Rowan (*Sorbus Aucuparia*). Leaf, natural size. (MOELLER.)

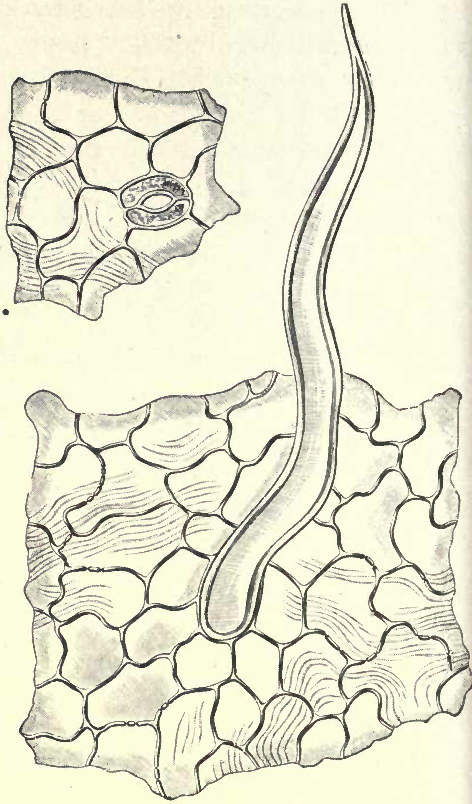

FIG. 373. Rowan. Epidermis of leaf with stoma and hair. (MOELLER.)

MULBERRY LEAVES.

The white and black mulberry trees (*Morus alba* L. and *Morus nigra* L., order *Moraceæ*), natives of Asia, are grown for their leaves in Southern Europe and other silk-producing regions, and elsewhere for their fruit or shade.

The leaves of the white mulberry are light green, ovate heart-shaped, unequal at the base, long-petioled, nearly smooth on the upper side (Fig. 374); those of the black species are dark green, heart-shaped with tapering point, regular at the base, short-petioled, with rough hairs on the upper side. Soft hairs occur sparingly on the under surface of both species

Epidermis (Figs. 375 and 376). On the upper side the cells are polygonal, while those of the under side are unusually small and have sin-

FIG. 374. Mulberry (*Morus alba*). Leaf, natural size. (MOELLER.)

uous walls. Stomata are present only on the under side. Large epidermal cells containing cystoliths occur on both sides, the cells about them forming rosettes. The hairs are unicellular, very long, thin-walled,

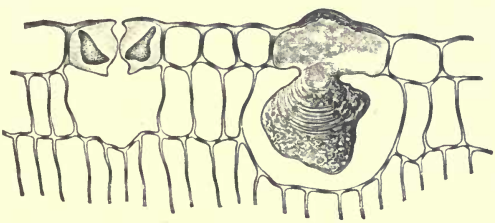

FIG. 375. Mulberry. Section of lower epidermis of leaf showing stoma and cystolith. (MOELLER.)

smooth, more or ess sinuous, but quite rigid. Glandular hairs with a unicellular base and multicellular head are also present.

The Mesophyl contains crystal rosettes.

COFFEE LEAVES.

Leaves of the coffee tree (*Coffea Arabica* L., order *Rubiaceæ*), like the seeds, contain caffein, although in smaller amount. They are used as

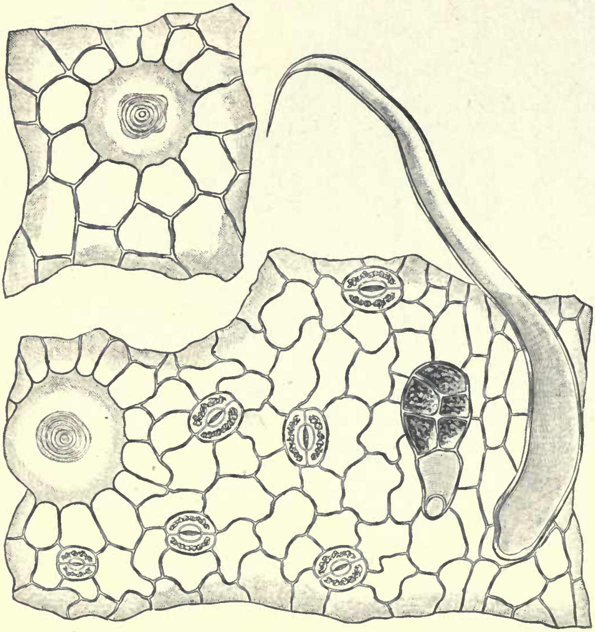

FIG. 376. Mulberry. Upper epidermis of leaf (above); lower epidermis with hairs, stomata and cystolith (below). (MOELLER.)

FIG. 377. Coffee (*Coffea Arabica*). Leaf, natural size. (MOELLER.)

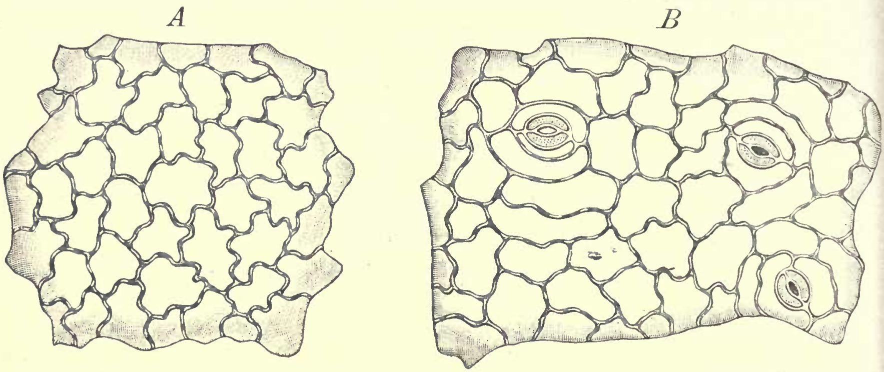

FIG. 378. Coffee. *A* upper epidermis of leaf. *B* lower epidermis. ×160. (MOELLER.)

substitutes for tea in coffee-growing countries, and their introduction into Europe has been suggested.

The leathery, smooth, shining, dark-green leaves are elliptical, tapering gradually to a point at the apex and into the short stem at the base (Fig. 377). Teeth are not present. The veins form sharp angles with the midrib, and anastomose with the formation of pronounced curves.

Epidermis (Fig. 378). The cells on both sides have sinuous walls. On the under side large stomata (25–45 μ) to the number of 60 per sq. mm. are distributed in a peculiar manner among the epidermal cells.

The Mesophyl contains crystal sand.

The leaf is prepared for use by roasting, and is never rolled like tea.

CAMELLIA LEAVES.

The camellia (*Camellia Japonica* L., order *Ternstroemiaceæ*) grows native in Japan, and is cultivated as a greenhouse plant in Europe and America. It is closely related to tea, but the leaves (Fig. 379) contain no caffein. On careful examination geniculate hairs similar to those of tea may be found on the young leaves, but only on the margins. These soon drop off, leaving the mature leaf smooth and lustrous. The leaf is similar to the tea leaf in form and venation, but is larger, broader and thicker.

FIG. 379. Camellia (*Camellia Japonica*). Leaf, natural size. (MOELLER.)

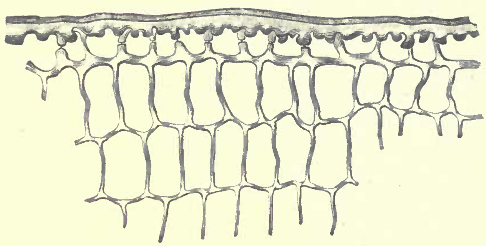

FIG. 380. Camellia. Epidermis of leaf in cross section. (MOELLER.)

Epidermis (Figs. 380 and 381). Cross-sections show that the strongly thickened and cuticularized outer walls have wart-like projections on their inner surfaces. In surface view the cells show broad pores, and in consequence of the projections are often very irregular in form. The stomata are often nearly circular, and occur only on the lower epidermis.

The Mesophyl contains idioblasts and oxalate crystals similar to those of tea.

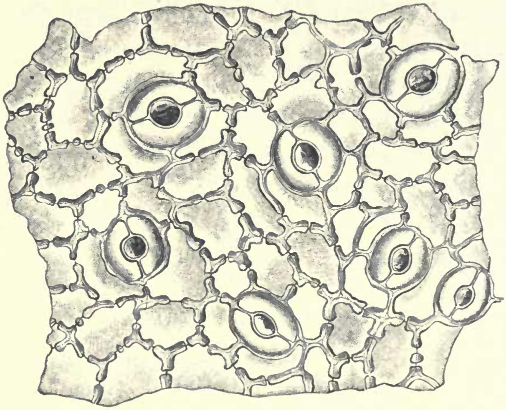

FIG. 381. Camellia. Lower epidermis of leaf. (MOELLER.)

FIG. 382. Cherry (*Prunus avium*). Leaf, natural size. (MOELLER.)

The leaves are said to be used as an adulterant of tea, although poorly suited for the purpose. The thick-walled epidermis is characteristic.

CHERRY LEAVES.

Leaves of the sweet cherry (*Prunus avium* L., order *Rosaceæ*) are seldom over 10 cm. long, about 5 cm. broad, oblong-ovate, taper-pointed, petioled, with numerous teeth on the margin, each with a small gland (Fig. 382). On one or both sides of the petiole is a brown, glistening gland.

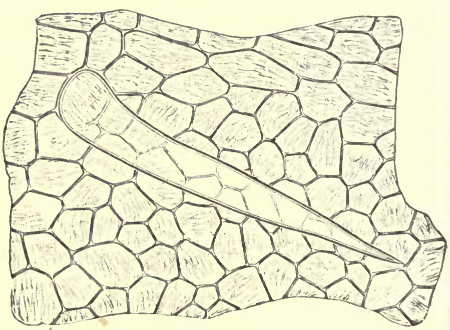

FIG. 383. Cherry. Upper epidermis of leaf. ×300. (MOELLER.)

The Upper Epidermis (Fig. 383) is made up of irregularly polygonal cells averaging 30 μ, with a very delicate, finely striated cuticle. Along the veins are a few unicellular, dagger-shaped hairs about 600 μ long and the same size at the base as the epidermal cells.

The Lower Epidermis (Fig. 384) consists of delicate cells with sinuous

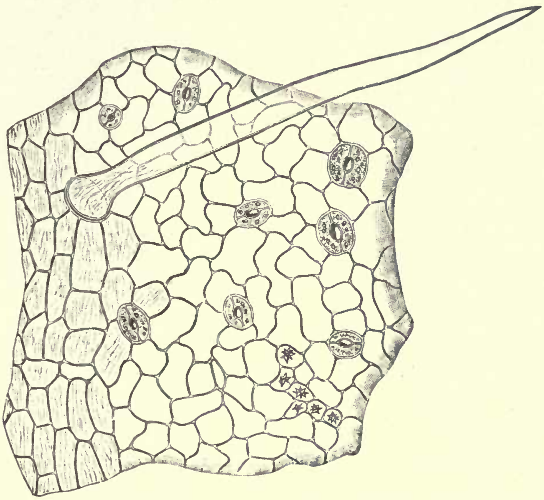

FIG. 384. Cherry. Lower epidermis of leaf. ×300. (MOELLER.)

walls, numerous circular or elliptical stomata and hairs of the same type as those on the upper epidermis, but longer and thinner-walled.

Noteworthy are the small oxalate rosettes occurring here and there in small epidermal cells.

The Mesophyl contains numerous oxalate rosettes, and accompanying the bundles, simple crystals.

The leaves of the sour cherry (*P. Cerasus* L.) are stiff, lustrous, and apparently smooth.

SLOE LEAVES.

The obovate or elliptical-lanceolate leaves of the sloe or black thorn (*Prunus spinosa* L.) resemble somewhat tea leaves. Their borders are sharply and irregularly toothed (Fig. 385). The veins form sharp angles with the midrib, and do not form distinct loops at the margin.

FIG. 385. Sloe (*Prunus spinosa*). Leaf, natural size. (MOELLER.)

The Upper Epidermis (Fig. 386) consists of thick-walled, polygonal cells with delicate striations, through which here and there shimmer simple crystals and rosettes.

The Lower Epidermis (Fig. 387) is more delicate than the upper, and the cuticle is striated only in places. The cells have slightly sinuous

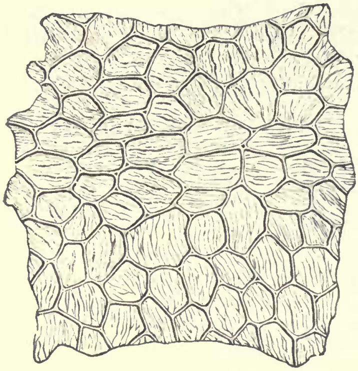

FIG. 386. Sloe. Upper epidermis of leaf. ×160. (MOELLER.)

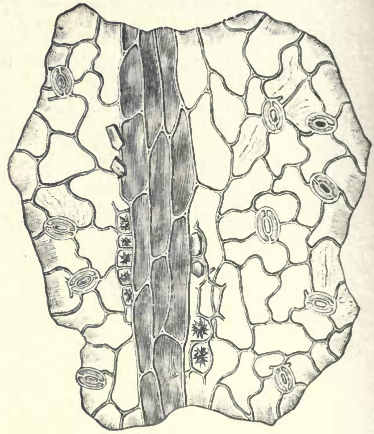

FIG. 387. Sloe. Lower epidermis of leaf, seen from below. The crystal cells are not in the epidermis but in the mesophyl, accompanying the fibro-vascular bundles. ×160. (MOELLER.)

walls, and are interspersed with numerous small (25 μ) stomata in groups, some of which have horns like those of the ash leaf.

The Mesophyl contains numerous crystal cells with rosettes or simple crystals of considerable size. Accompanying the fibro-vascular bundles, particularly on the under side, are crystal fibers, some of which on removing the epidermis adhere to it. Unicellular, rather thick-walled, often sinuous hairs are found along the veins and on the margins.

FIG. 388 Rose (*Rosa canina*). Leaf-let, natural size. (MOELLER.)

ROSE LEAVES.

The leaflets of the odd-pinnate leaves of the rose (*Rosa canina* L., and other species) are easily distinguished from tea leaves by their greater breadth, rounded base, dense and sharp serration, and vein-meshes (Fig. 388). Each tooth ends in a multicellular gland.

The Epidermis (Fig. 389) is similar to that of the sloe, but the cuticle is smooth, and the walls are in many parts knotty and thickened. Many of the cells, along the veins, are filled with a homogeneous brown substance. The stomata on the lower epidermis are rounded elliptical, of considerable size (35–40 μ) without accompanying cells.

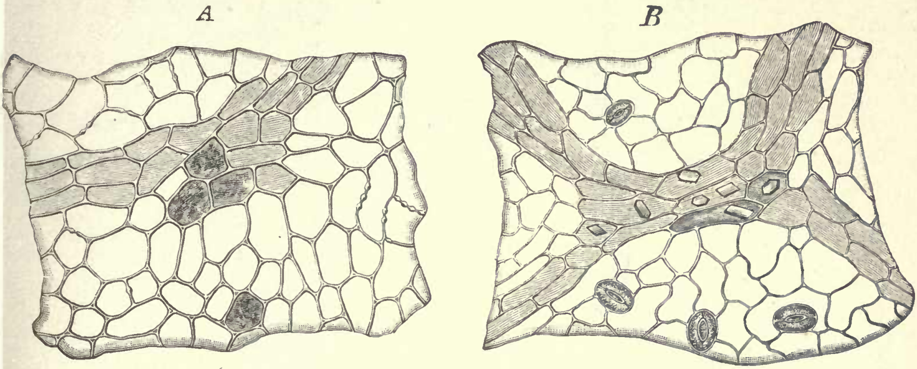

FIG. 389. Rose. *A* Upper epidermis of leaf. *B* lower epidermis seen from below; also crystals from mesophyl. $\times 160$. (MOELLER.)

STRAWBERRY LEAVES.

The wood strawberry (*Fragaria vesca* L., order *Rosaceæ*), has long-petioled, trifoliate leaves with coarsely serrate leaflets irregular at the

FIG. 390. Strawberry (*Fragaria vesca*). Leaflet, natural size. (MOELLER.)

base and hairy underneath (Fig. 390). There are as many veins as teeth, each vein ending in a tooth.

The Epidermis (Figs. 391 and 392) of both sides is similar, except that the cells on the under side have thinner walls, which are sinuous. Two

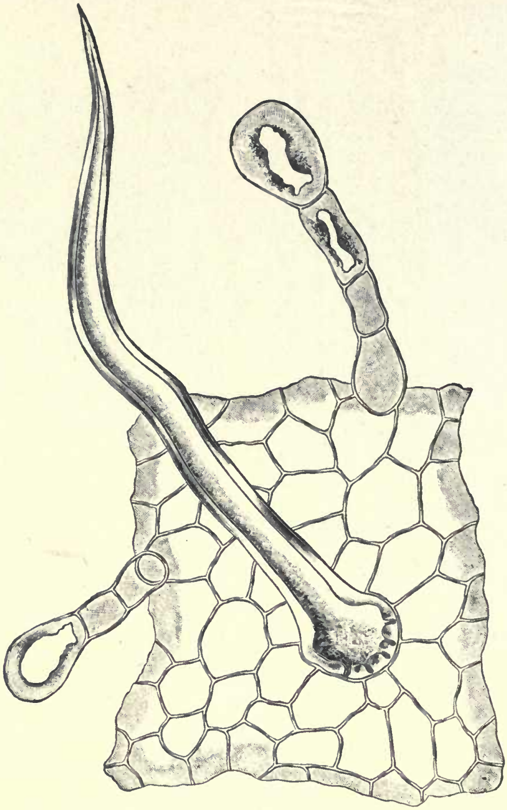

FIG. 391. Strawberry. Upper epidermis of leaf. (MOELLER.)

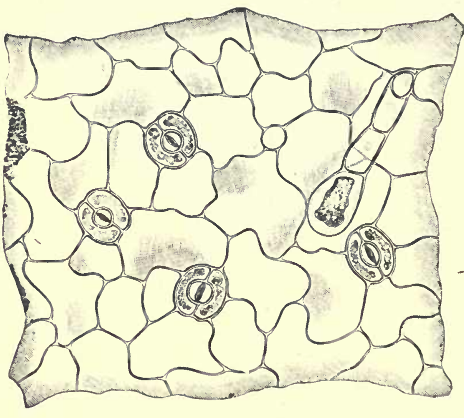

FIG. 392. Strawberry. Lower epidermis of leaf. (MOELLER.)

forms of hairs occur on both surfaces: (1) very long, unicellular, rigid and mostly straight, with thick porous base, and (2) multicellular, with globular heads, the thin walls swelling greatly in alkali.

The Mesophyl contains great numbers of large simple crystals.

MEADOWSWEET LEAVES.

Meadowsweet (*Spiræa Ulmaria* L., order *Rosaceæ*) grows wild in Europe and Asia and is also cultivated for its flowers, which were once used in medicine.

The interruptedly pinnate leaves have irregularly pointed, ovate side

FIG. 393. Meadowsweet (*Spiraea Ulmaria*). Leaflet, natural size. (MOELLER.)

leaflets, and 3–5 lobed end leaflets (Fig. 393). Both forms are compoundly serrate. The ribs and veins are prominent on the under surface, and bear rough hairs. The veins anastomose some distance from the edge and send off branches into the teeth.

The Epidermis (Figs. 394 and 395) of both sides is delicate, and not

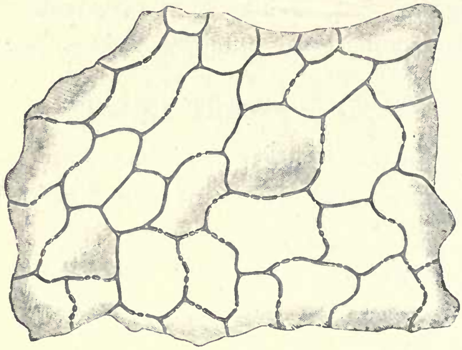

FIG. 394. Meadowsweet. Upper epidermis of leaf. (MOELLER.)

easily separated from the leaf. On the upper side the walls are slightly wavy, on the under side deeply wavy. Stomata occur only on the under side, hairs of three forms on both sides, but chiefly along the veins on the under side. The hairs on the body of the leaf are mostly unicellular, dagger-shaped, often sinuous, with

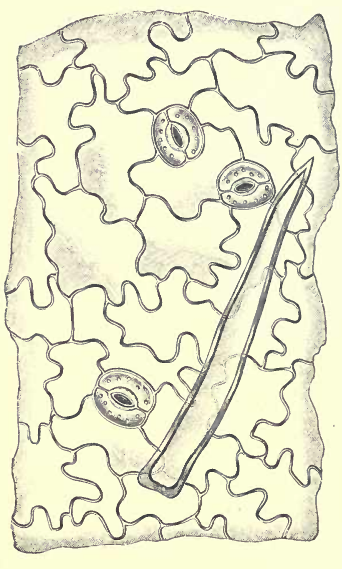

FIG. 395. Meadowsweet. Lower epidermis of leaf. (MOELLER.)

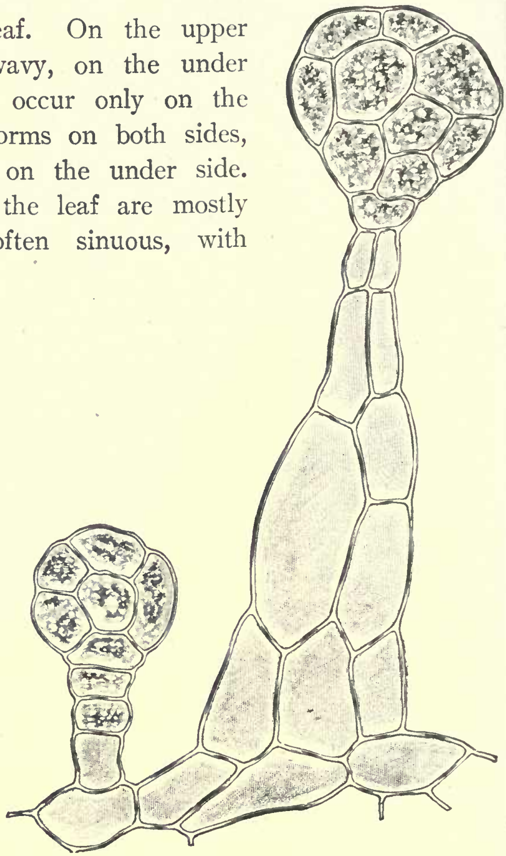

FIG. 396. Meadowsweet. Glandular hairs of leaf. (MOELLER.)

deeply-planted, rounded-angular base. On the veins, glandular hairs, some with short jointed stems, others with long two-rowed stems, predominate (Fig. 396). The heads of both forms are multicellular and globular.

The Mesophyl contains a few crystal rosettes chiefly along the midrib.

WISTARIA LEAVES.

In Japan the odd-pinnate leaves of *Wistaria Sinensis* DC. (*Kraunhia floribunda* Taubert, order *Papilionaceæ*) are used as an adulterant of tea. The leaflets are ovate-lanceolate, entire, slightly plaited at the margins, not petioled (Fig. 397). The prominent veins form near the margin indistinct loops.

FIG. 397. Wistaria (*Wistaria Sinensis.*) Leaflet natural size. (MOELLER.)

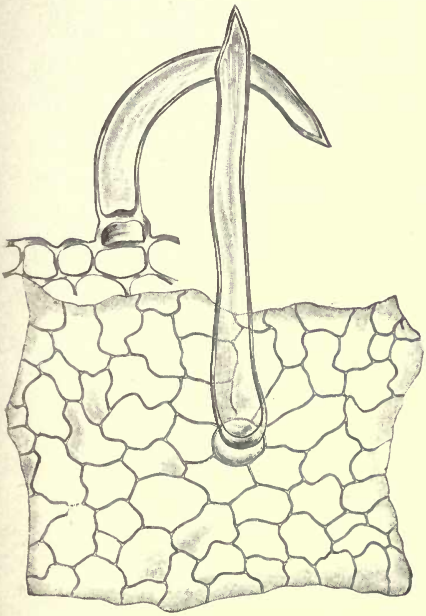

FIG. 398. Wistaria. Upper epidermis of leaf in cross section and surface view. (MOELLER.)

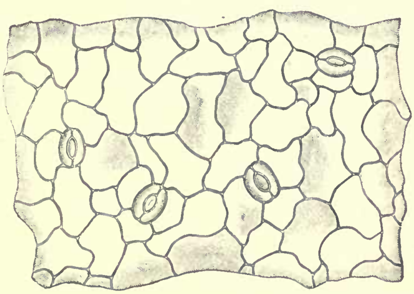

FIG. 399. Wistaria. Lower epidermis of leaf. (MOELLER.)

The Epidermis (Figs. 398 and 399) consists of cells with thin wavy walls and curious hairs, made up of a short basal cell, a short thick-walled middle cell and a long, straight or sickle-shaped, thin walled, pointed end cell. Stomata occur only on the under side.

Simple crystals accompany the bundles.

FIG. 400. Hydrangea (*Hydrangea Hortensia*). Leaf, natural size. (MOELLER.)

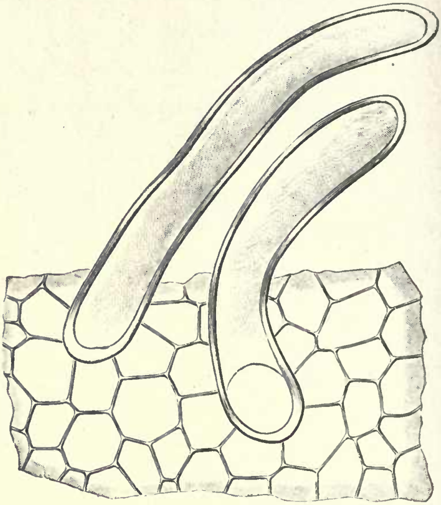

FIG. 401. Hydrangea. Epidermis of leaf with hairs. (MOELLER.)

HYDRANGEA LEAVES.

This shrub (*Hydrangea Hortensia* DC., order *Saxifragaceæ*), is a native of Japan and northern China. In Japan the leaves are employed as a tea substitute under the name of "Ama-cha." [1] They reach the size of the

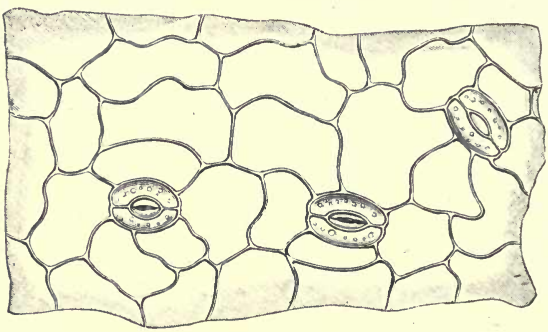

FIG. 402. Hydrangea. Lower epidermis of leaf. (MOELLER.)

[1] Kellner, Hayakawa, and Kamoshita: Mittlg. d. deutsch Ges. f. Nat. u. Völkerk. Ostasiens. IV.

hand and are short-petioled, pointed-ovate, entire below, unequally dentate above (Fig. 400). The veins extend in gentle curves almost to the margin, where they anastomose and send off branches into the teeth.

Epidermis (Figs. 401 and 402). The cells are polygonal or sinuous in outline. Unicellular hairs with rounded base and apex occur only along the veins.

The Mesophyl contains raphides.

MAPLE LEAVES.

The leaves of most maples are palmately lobed, but in the ash-leaved species (*Acer Negundo* L., or *Negundo fraxinifolium* Nutt, order *Aceraceæ*) they are odd-pinnate, somewhat resembling tea. Each leaflet is short-petioled, ovate-lanceolate, coarsely but sparingly toothed (Fig. 403). The veins form indistinct loops near the margin. To the naked eye they appear smooth, but under the lens they are hairy on the margins.

FIG. 403. Ash-leafed Maple (*Acer Negundo*). Leaf, natural size. (MOELLER.)

Epidermis (Fig. 404). The cells are irregularly polygonal. Stomata occur on both surfaces, also: (1) unicellular smooth or warty hairs with rounded base, blunt point and slightly thickened walls, swelling and becoming stratified with alkali; (2) glandular hairs with 2–3 celled stem and unusually large head.

The Mesophyl contains large simple crystals.

OAK LEAVES.

Oak leaves of different species are widely different in form and size. The description here given applies to two European species (*Quercus pedunculata* Ehrh., and *Q. sessiliflora* Sm., order *Fagaceæ*).

Epidermis (Figs. 406 and 407). Polygonal cells and 2–3 celled hairs with rounded apex and, often, broad base, are found on both surfaces; stomata only on the lower surface.

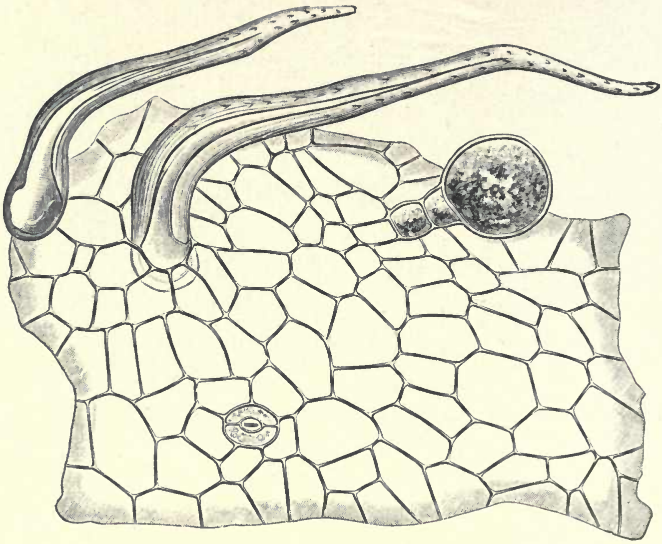

FIG. 404. Ash-leafed Maple. Upper epidermis of leaf. (MOELLER.)

FIG. 405. Oak (*Quercus* sp.). Leaf, natural size. (MOELLER.)

Mesophyl. The bundles are accompanied by simple crystals.

AKEBIA LEAVES.

According to Kellner[1] the leaves of "Fagi-Kadsura-Akebi" (*Akebia quinata* (Thbg.) Decaisne, order *Lardizabalaceæ*), a perennial climbing plant, are used in Japan as a tea substitute. The plant is cultivated in the Occident for ornament.

The obovate, entire, petioled leaflets are smooth, with four or less delicate veins, forming broad loops (Fig. 408).

Epidermis (Figs. 409 and 410). On the upper side the cells are large, with pronounced wavy walls; on the under side they are smaller and more nearly polygonal, and usually have papillæ similar to those of cocoa leaves, although not so

[1] Loc. cit.

strongly thickened. These papillæ are not found on the four or more cells adjoining the stomata.

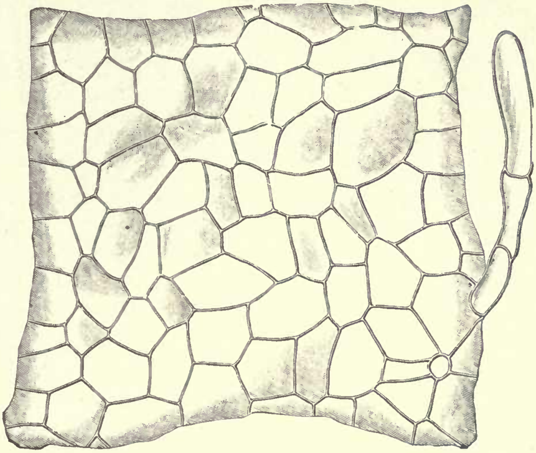

FIG. 406. Oak. Upper epidermis of leaf. (MOELLER.)

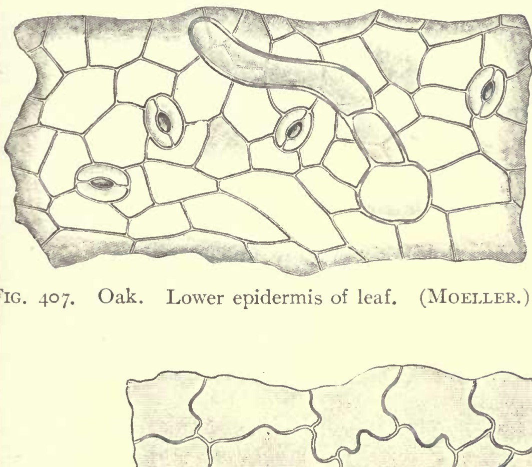

FIG. 407. Oak. Lower epidermis of leaf. (MOELLER.)

FIG. 408. Akebia (*Akebia quinata*). Leaflet, natural size. (MOELLER.)

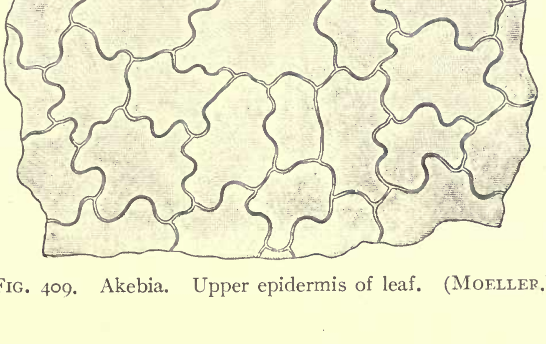

FIG. 409. Akebia. Upper epidermis of leaf. (MOELLER.)

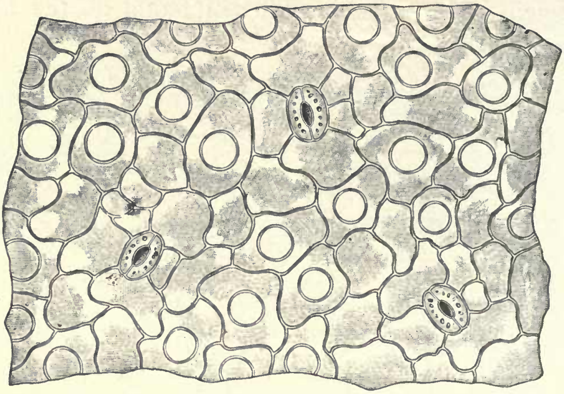

FIG. 410. Akebia. Lower epidermis of leaf. (MOELLER.)

Mesophyl. A few simple crystals accompany the bundles.

BLUEBERRY LEAVES.

Of the numerous species of blueberries, the common European species (*Vaccinium Myrtillus* L., order *Ericaceæ*) is here described. The leaves are ovate, finely serrate and lustrous (Fig. 411). The veins are not

FIG. 411. European Blueberry (*Vaccinium Myrtillus*). Leaf, natural size. (MOELLER.)

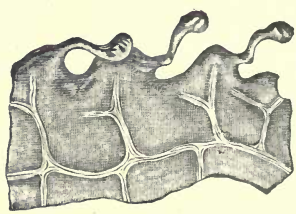

FIG. 412. European Blueberry. Margin of leaf with teeth, under a lens. (MOELLER.)

prominent, but form a beautiful network. Under a lens each tooth is seen to end in a stalked gland (Fig. 412).

Epidermis (Figs. 413 and 414). On the upper side stomata are absent, and the cells are either isodiametric, deeply sinuous, or, along the veins, elongated, slightly sinuous. Unicellular, warty, sickle-shaped hairs and multicellular glandular hairs like those of the teeth, accompany the elongated cells. The lower epidermis consists of deeply sinuous cells, stomata with 4–5 accompanying cells, and glandular hairs like those described. Hanausek finds that if the margin is boiled with dilute potash, numerous

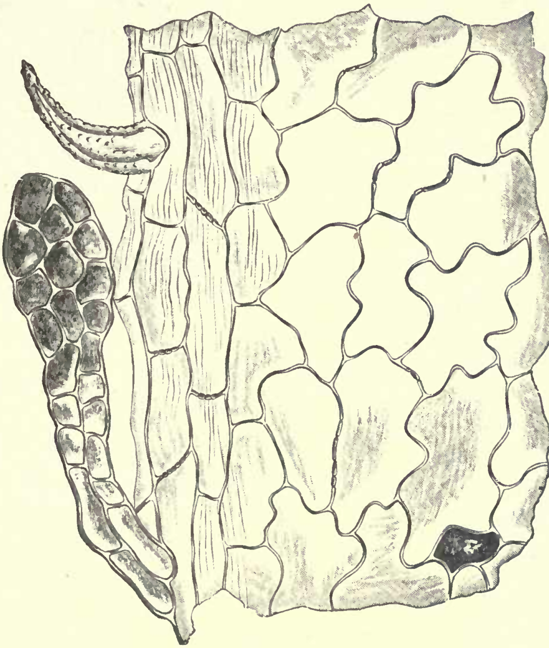

FIG. 413. European Blueberry. Upper epidermis of leaf. (MOELLER.)

fine crystals, soluble in acetic acid, separate from the glandular secretion.

Mesophyl. Simple crystals occur in crystal fibers or singly.

CAUCASIAN TEA.

In Russia the leaves of *Vaccinium Arctostaphylos* L. are prepared like tea. Leaves of this species are considerably larger than the preceding species, leathery, finely serrate, appearing smooth to the naked eye. The veins on the under side are prominent, forming indistinct loops distant from the margin. Under the lens hairs are evident along these veins, also a glandular hair on each tooth.

Epidermis (Figs. 415 and 416). The upper epidermal cells are polygonal, thick-walled, often porous, with a striated cuticle; those of the lower epidermis are sinuous, with thin walls. Unicellular, thick-walled

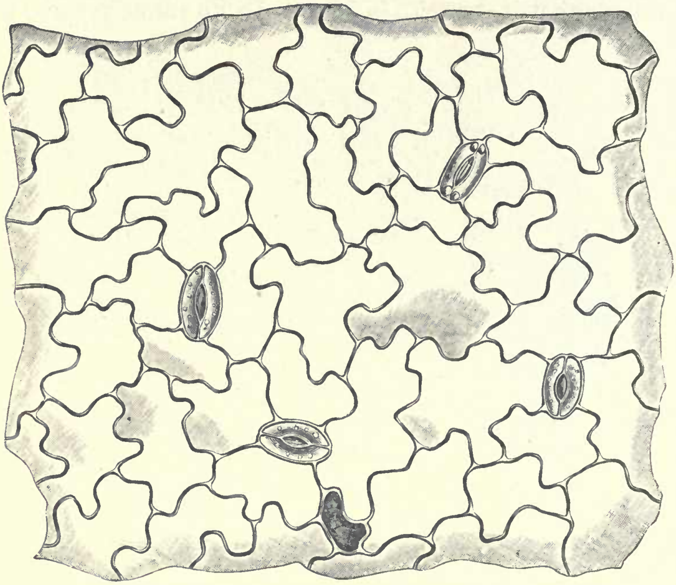

FIG. 414. European Blueberry. Lower epidermis of leaf. (MOELLER.)

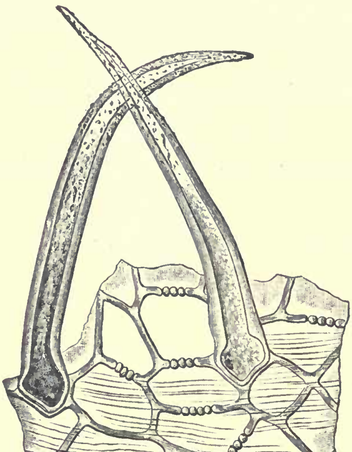

FIG. 415. Caucasian Tea (*Vaccinium Arctostaphylos*). Upper epidermis of leaf. (MOELLER.)

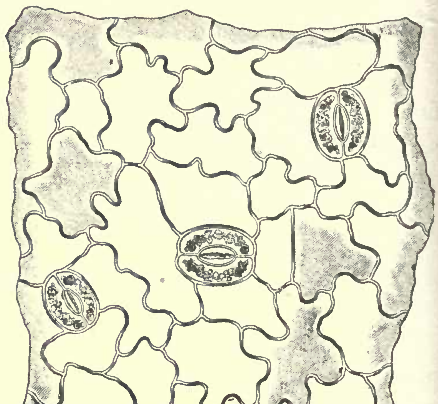

FIG. 416. Caucasian Tea. Lower epidermis of leaf. (MOELLER.)

warty hairs occur on both surfaces, but in the greatest numbers along the midrib on the under side. Glandular hairs occur not only on the teeth but also, sparingly, on the surface. Hanausek notes a third form, designated "bladder hairs."

Mesophyl. Crystal rosettes and simple crystals are present, the latter along the bundles.

OTHER TEA SUBSTITUTES.

Maté, the only substitute for tea containing caffein, is described below. Leaves of the following plants are or have been used as substitutes in the regions named:

North America: Species of *Ledum* (Labrador Tea); *Ceanothus Americanus* L. (New Jersey Tea); species of *Monarda* (Oswego Tea); *Chenopodium ambrosioides L.* (Mexican Tea).

South America: *Lantana pseudothea, Stachytarpheta Jamaicensis, Psoralia glandula, Myrtus Ugni, Alstonia theæformis, Capraria biflora, Angrecum fragrans,* and *Eritrichium gnaphaloides.*

China: *Sageretia theezans.*

Australia: Species *Myrtaceæ.*

MATÉ.

Maté, Paraguay tea, or Jesuit tea, is prepared from the leaves of *Ilex Paraguariensis* St. Hil. (order *Aquifoliaceæ*), a small tree growing in South America. The leafy branches are cut from the tree and dried by artificial heat, after which the leaves are stripped off and ground to a coarse powder. In this form it is placed on the market as a substitute for tea. It is quite commonly used in South America, but not to any extent in other regions, notwithstanding repeated efforts of promoters. The product contains as high as 20 per cent of tannin and a considerable amount of caffein (0.5–0.9 per cent).

Fig. 417. Maté (*Ilex Paraguariensis*). Leaf, natural size. (Moeller.)

The leaves are up to 13 cm. or more long and 4 cm. broad, ovate or nearly spatulate, tapering to the short petiole, blunt or rounded at the apex. They are dentate, smooth but only slightly lustrous, and leathery (Fig. 417). The veins form sharp loops at some distance from the margin. The secondary veins are also distinct.

HISTOLOGY.

Epidermis (Figs. 418 and 419). On both sides the cells are more or less polygonal, with striated cuticle. Along the veins they are arranged

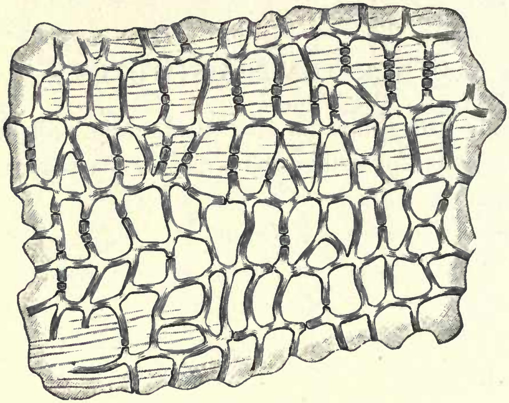

FIG. 418. Maté. Upper epidermis of leaf, from one of the veins. (MOELLER.)

side by side in rows. Numerous stomata, larger than the surrounding cells, occur on the lower epidermis.

The Mesophyl contains oxalate rosettes. Thick strands of fibers accompany the bundles.

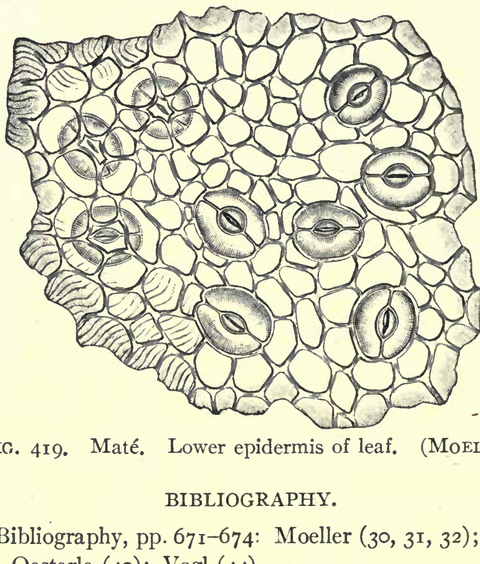

FIG. 419. Maté. Lower epidermis of leaf. (MOELLER.)

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Moeller (30, 31, 32); Planchon et Collin (34); Tschirch u. Oesterle (40); Vogl (44).

CADOR: Anatomische Untersuchungen der Mateblätter unter Berücksichtigung ihres Gehaltes an Teïn. Bot. Centralbl. 1900.

COLLIN: Du maté ou thé du Paraguay. Journ. pharm. chim., 1891.
COLLIN: Journ. pharm. 1886.
DOUBLET: Le maté. Paris, 1885.
LOESENER: Beiträge zur Kenntnis der Matepflanzen. Ber. deutsch. pharm. Ges. 1896. Notizbl. d. königl. Bot. Gartens u. Museums in Berlin, 1897. Verh. d. bot. Ver. d. Provinz Brandenburg, 1891.
NEGER und VANINO: Der Paraguay-Tee. Stuttgart, 1903.
POLENSKE u. BUSSE: Beiträge zur Kenntnis der Matesorten des Handels. Arb. des kaiserl. Gesundheitsamtes, 1898.

COCA.

The leaves of the coca shrub (*Erythroxylon Coca* Lam., order *Erythroxylaceæ*) have been chewed by South American natives for generations. Of late years they have been in demand for the preparation of cocaine, the well-known anæsthetic. The full-grown leaves (Fig. 420) are 6–8 cm. long, half as broad, ovate, blunt or rounded at the apex, short-petioled, smooth, light green beneath. The midrib extended beyond the apex forms a short prickle. The veins anastomose some distance from the entire but slightly revolute margin, while the veinlets form a delicate network with wide meshes. On holding a leaf to the light, two slender curved

FIG. 420. Coca (*Erythroxylon Coca*). Leaf, natural size. (MOELLER.)

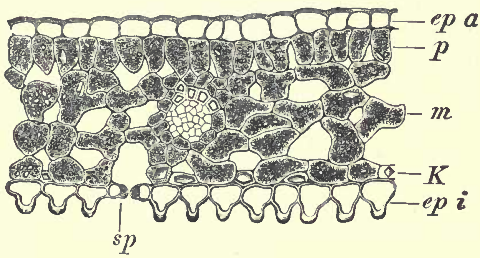

FIG. 421. Coca. Leaf in cross section. *epa* upper epidermis; *p* palisade cells; *m* spongy parenchyma with bundle and *K* crystal cell; *epi* lower epidermis with *sp* stoma. ×160. (MOELLER.)

ribs running each side of the midrib from base to apex are evident. These are not at all connected with the venation, but serve to stiffen the leaf.

HISTOLOGY.

Cross sections show a small-celled upper epidermis with a thin cuticle, a single layer of moderately elongated palisade cells, a loose spongy parenchyma pierced by vascular bundles, and finally the lower epidermis of curiously humped cells (Fig. 421).

The Upper Epidermis (Fig. 422) consists of somewhat thick, polygonal cells with a finely granular cuticle.

The Lower Epidermis (Fig. 423) has walls similar to those of the upper, but somewhat wavy. In the middle of each is a hump-like papilla which

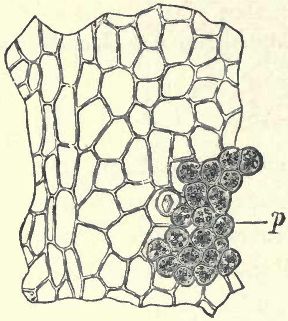

FIG. 422. Coca. Upper epidermis of leaf and *p* palisade cells, from below. ×160. (MOELLER.)

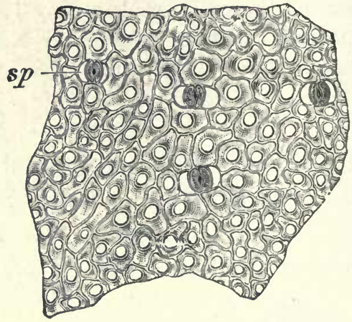

FIG. 423. Coca. Lower epidermis of leaf with *sp* stoma. ×160. (MOELLER.)

in surface view appears like a circle with double contour. The stomata are very small (20–30 μ), and are flanked by two accompanying cells without papillæ.

Mesophyl. Monoclinic crystals are abundant, particularly on the under side of the bundles. In the false ribs the subepidermal tissue is not spongy but collenchymatous, thus strengthening the leaf.

The venation and the lower epidermis are characteristic.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Koch, L. (22); Moeller (30, 31, 32); Planchon und Collin (34); Tschirch u. Oesterle (40); Vogl (44).

HARTWICH: Beitr. z. Kenntnis d. Cocablätter. Arch. d. Pharm. 1903.

HARTWICH: Beitr. z. Kenntnis d. Cocablätter. Pharm. Praxis, 1904.

HARTWICH: "Coca" in Realenzykl. d. ges. Pharm. 2. Aufl., III. 1904.

MOELLER: Die Falten des Cocablattes. Pharm. Post, 1891.

NEVINNY: Das Cocablatt. Wien, 1866.

TOBACCO.

Two species (*Nicotiana Tabacum* L., *N. rustica* L., order *Solanaceæ*) and their varieties, yield the tobacco of commerce. These plants, natives of the New World, were first introduced into Europe in 1586 by Francis Drake.

FIG. 424. Tobacco (*Nicotiana Tabacum*). Small leaf, natural size. (MOELLER.)

Tobacco leaves are ovate or ovate-lanceolate, entire, up to ½ meter long, broad or rather narrow, petioled or sessile (Fig. 424). They are glandular-hairy. The veins form loops near the margins.

HISTOLOGY.

The general structure of the leaf is learned from cross-sections (Fig. 425); the details of chief value in diagnosis from surface preparations of the epidermis (Figs. 426 and 427).

Epidermis. The cells are large, and on the lower surface have dis-

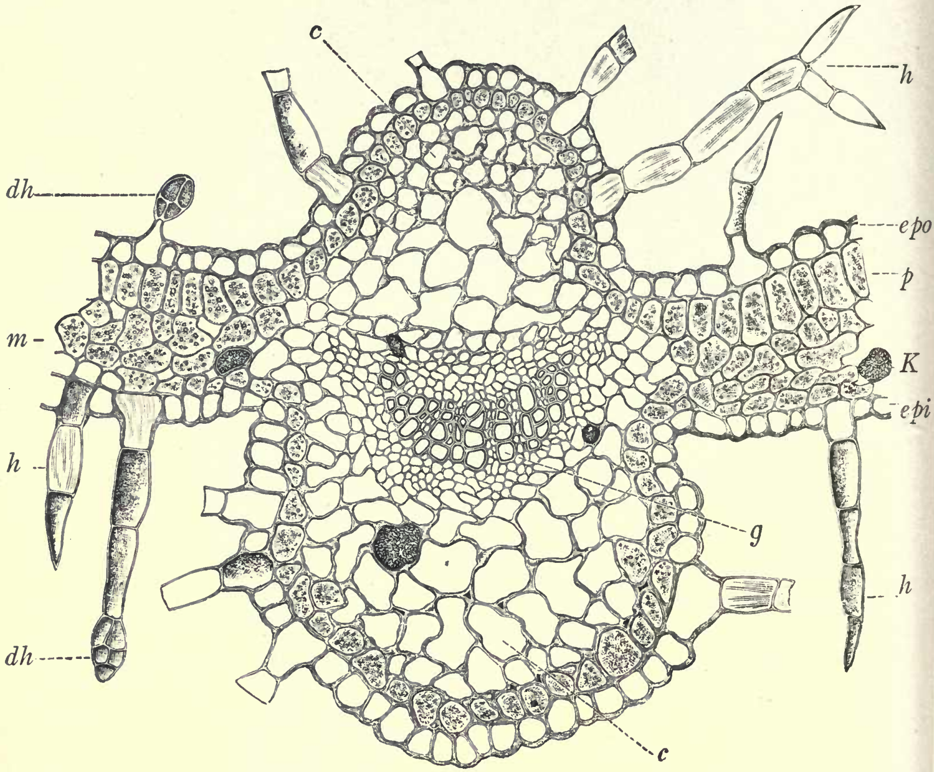

FIG. 425. Tobacco. Cross section through midrib. *epo* upper epidermis; *p* palisade cells; *m* spongy perenchyma; *c* collenchyma; *epi* lower epidermis; *g* fibro-vascular bundle; *K* crystal sand; *h* jointed hair; *dh* glandular hairs. ×100. (MOELLER.)

tinctly wavy walls. Stomata are about three times as numerous on the under surface as on the upper. The clammy hairs are all multicellular, with thin walls and a broad base, but are of four forms: (1) jointed with pointed or blunt apex; (2) like the first, but branching; (3) glandular with multicellular head and jointed stem; (4) like the last, but with short unicellular stem. The first three forms reach an extraordinary

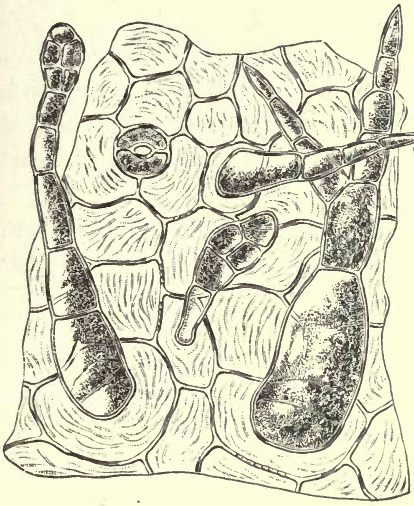

FIG. 426. Tobacco. Upper epidermis. ×160. (MOELLER.) FIG. 427. Tobacco. Lower epidermis. ×160. (MOELLER.)

length, and are usually evident to the naked eye. The cuticle is striated and often granular on the surface.

Mesophyl. The chlorophyl parenchyma is brown. Numerous cells filled with crystal sand are present.

DIAGNOSIS.

The characteristic elements are the epidermis with the four forms of multicellular hairs, also the mesocarp cells with crystal sand. The epidermal cells with hairs are readily found in surface preparations of fragments from cigars, smoking and chewing tobacco, also in powder mounts of snuff. The latter, being made from the coarser part of the leaf, contains a preponderance of vascular elements. Before searching for adulterants the material should be boiled with dilute alkali, filtered and washed.

Hauenschild states that leaves of the following are used in tobacco: Cherry, artichoke, linden, acacia, walnut, sunflower, arnica, watercress, hemp, rose, oak, dock, betony, chestnut, melilot, and especially beet, cabbage, chicory, and potato. In the manufacture of plug tobacco the following materials are employed: Common salt, sirup, sugar, licorice, rum, sal-ammoniac, prunes, tamarinds, vanilla, essential oils, benzoic acid, carob beans, saltpetre, potash, cloves, anise, violet root, gum, dextrine, etc. Various materials, in powder form, may be used as adulterants.

In Germany the revenue law allows the addition to tobacco of a certain percentage of cherry and rose leaves (see pp. 468–471). English laws prohibit the use of the following: Sugar, sirup, molasses, honey, malt sprouts, roasted seeds, chicory, lime, sand, umber, ocher or other earths, seaweed, roots, moss, and all leaves and herbs.

Some of the leaves used as adulterants are described elsewhere in this work; others must be learned by experience. Usually all that is necessary is to prove that the leaf is not tobacco.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Moeller (30, 31, 32); Molisch (33); Planchon et Collin (34); Vogl (44); Krasser (48).

KONING: Der Tabak. Leipzig, 1900.

KISSLING: Der Tabak. Berlin, 1893.

PART IX.

SPICES AND CONDIMENTS.

SPICES AND CONDIMENTS.[1]

Under the head of spices and condiments are here grouped all products used merely for flavoring. They include certain fruits (pepper, cayenne, allspice, anise, vanilla, etc.), seeds (nutmeg, mustard, etc.), roots (ginger, horseradish, etc.), barks (cassia, cinnamon, and clove bark), flower buds (cloves, capers, cassia buds), leaves and herbs (sage, savory, bay leaf, etc.).

Mustard seeds are described for convenience with other cruciferous seeds in the section on oil seeds.

Turmeric, a root allied to ginger, and saffron, the stigmas of *Crocus sativus*, although chiefly valuable as dyes, are also classed as spices.

The valuable constituents of most spices are essential oils, although the pungent principles of mustard and horseradish are sulphur compounds, and the capsicin of cayenne pepper and paprika, as well as the vanillin of the vanilla bean, are crystalline solids. The tissues and other elements, although useless for seasoning, are of chief service in diagnosis.

The Impurities of spices introduced through accident or through faulty methods of collecting, curing, cleaning, and handling, include dirt, small stones, woody matter, extraneous parts of the plant, weed seeds, and insect contamination.

Mineral Matter. Dirt in the form of dust is deposited during the growing or ripening periods on fruits, barks and leaves, but not, of course, on seeds protected by the pericarp. It is washed off to some extent by rains, but, on the other hand, rains often spatter mud on low-growing plants, thus seriously injuring the quality of the product. It is well known in the trade that, for this reason alone, cayenne pepper, sage, and other spices, differ greatly from year to year in cleanness.

Certain commercial varieties of black pepper, such as Acheen,

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[1] The descriptions of barks (excepting cassia), rhizomes, leaves, and flowers are by Prof. J. Moeller.

Lampong, Tellicherry, etc., are sun-dried on the ground, and as a consequence are contaminated with lumps of dirt, stones, sticks, etc., while Singapore pepper, being a fire-dried product, is much cleaner.

Ginger and other roots are freed from adhering soil by washing, but the undecorticated sorts, such as African and Calcutta, are seldom absolutely clean when placed on the market.

Scraped cassia and Ceylon cinnamon are usually quite clean, while unscraped cassia, and particularly cassia chips, are often more or less contaminated with adhering dirt. Low grade or broken China cassia is particularly dirty.

Limed nutmegs and " bleached " ginger are coated with a thin layer of calcium carbonate which is said to prevent the ravages of insects, and is not, therefore, regarded as an adulteration.

Penang white pepper is invariably coated with a brown-gray layer consisting largely of calcium carbonate.

Extraneous Matter from the plant itself, such as stems in cayenne pepper, cloves, allspice, umbelliferous fruits, and various leaves, also shells in nutmegs and pepper, should be present only in very small quantities in properly cleaned spices. The fact that the impurity is produced by the same plant as yields the spice is no valid excuse for not removing such an impurity or for its willful addition. Clove stems, for example, are as much an adulterant in ground cloves, as would be sawdust made from the clove tree.

Weed Seeds are accidental impurities of mustard and umbelliferous seeds, from which they can be largely removed by sifting. Most of the other common spices, are not subject to this kind of contamination.

Insects, although avoiding certain spices rich in essential oil, cause great havoc in certain others. The drug-store beetle is almost sure to make its appearance in whole unlimed ginger, if stored for a long time, burrowing through the roots and transforming nearly the whole product into an unappetizing powder. Cayenne pepper and paprika, both whole and ground, are attacked by a small moth which spins a dense web through the material. Nutmegs used for grinding are often light-weight kernels from which the starchy matter has been almost entirely eaten out by insects, leaving only the brown resinous veins. Mites and other insects infesting cereal products, also occur in mustard flour mixed with wheat flour, corn meal, and other cereal adulterants.

Adulterants. Probably no class of products are so frequently or so grossly adulterated as ground spices. The incentive is unusually great owing to their high cost and their strong odor, which conceals a considerable admixture of worthless material.

A list of the adulterants includes a great variety of cheap materials in powder form, and also certain dyes and pigments, added to conceal the makeweights.

Inorganic Materials. These are partly diluents, such as calcium sulphate, calcium carbonate, brick-dust, coal-ashes, sand and clay, and partly pigments, such as Venetian red and chrome yellow. Because of their greater weight they are used less often than vegetable materials. Calcium sulphate (plaster of Paris or gypsum) is occasionally added to mustard flour and ground ginger, but not to the dark-colored spices. Brick-dust has been found in cayenne pepper, coal-ashes in white pepper, and sand in various spices. Venetian red (iron oxide) is used in imitating the color of cloves, allspice, cinnamon, and nutmeg, while chrome yellow formerly was used in mustard.

Organic Material. Among the numerous diluents of vegetable origin are flour, bran and chaff of the cereals; hulls, bran, and other products of buckwheat; screenings; peas, beans, and other legumes; linseed meal, cottonseed meal, ground cocoanut cake, and other oil cakes; cocoanut shells (raw and charred), almond shells, and other nut shells; olive stones; sawdust, red sandalwood, and other woody materials; clove stems, mustard hulls, pepper shells, exhausted spices, and other waste products from spices. Other adulterants are: cayenne pepper, added to adulterated black pepper to reinforce its pungency; turmeric and other dyes used to color mustard; red coal-tar dyes added to cayenne pepper; and finally Bombay mace, a worthless substitute for true mace. This list is far from complete, but includes the materials most commonly employed.

The analyst will be greatly aided in his search by a knowledge of the available materials and commercial practices in his own country. For example, ground hazelnut shells is a distinctively European adulterant, while ground cocoanut shells is distinctively American; also rape, sunflower, and several other oil cakes are used in Europe, while only linseed and cottonseed cakes are commonly available in America.

Hints on the detection of foreign materials are given in the final section under each spice.

Identification of Ground Spices in spice mixtures or other food products is sometimes desirable, and for this purpose the key on p. 498 may be found useful.

METHODS OF EXAMINATION.

Preliminary Examination. The odor and especially the taste of the different spices is, as a rule, so characteristic, that complete substitution of other products would be recognized even by a layman. But adulterations with inert substances are not so readily detected by either the sense of smell or of taste, although one with experience will often find cause for suspicion.

The color is a valuable guide, as it is no easy matter to color fraudulent mixtures so as to exactly imitate the genuine. For example, colored mustard flour is almost always much yellower than the uncolored, and colored cayenne pepper is of a somewhat different shade from the genuine.

Texture and "grain" are also altered by the addition of foreign substances.

After removing the finer material by sifting, or separating into strata by jarring on a sheet of paper, suspicious fragments may often be picked out under a lens. These are first examined as to their color, texture, hardness and similar physical characters and then crushed or macerated for microscopic examination.

Chemical Analysis. The following determinations, applicable to most of the spices, are of value in diagnosis: total ash, ash soluble in water, sand (ash insoluble in hydrochloric acid), fixed oil (non-volatile ether extract), essential oil (volatile ether extract), alcohol extract, crude fiber, crude starch (copper-reducing matters by direct inversion), pure starch (by the diastase method), and total nitrogen.

If the quantity of ash is excessive, it should be examined for sand, calcium sulphate, iron oxide, and similar impurities.

Determination of essential oil is especially valuable in the examination of cloves, as this spice normally contains as high as 20 per cent of this constituent, but in the examination of other spices is of lesser importance, the percentage being usually small and exceedingly variable.

Although possessing no pungent qualities, certain fixed oils are characteristic constituents of mustard, mace, cayenne, and other spices.

Determination of crude fiber aids greatly in detecting nut shells, sawdust and similar woody adulterants, while determination of starch serves both to detect starchy adulterants in non-starchy spices, and non-starchy adulterants in starchy spices.

Among the processes applicable only to certain spices are the determination of crude piperine (nitrogen in the non-volatile ether extract) in black and white pepper; of cold-water extract in ginger (to detect exhausted ginger); of tannin in cloves and allspice; also the qualitative tests for Bombay mace, turmeric, coal-tar colors, etc.

Microscopical Examination is by far the most valuable, and in many cases the only, means of detecting vegetable adulterants in spices. Even in cases where chemical analysis furnishes evidences of foreign admixtures, microscopic examination is usually essential to determine the nature and origin of that admixture. As a rule this examination coupled with a determination of ash is all that is needed in pronouncing on a suspected sample.

The microscopist who undertakes this work should have at his command for comparison authenticated samples of whole and ground spices as well as of spice adulterants.

Direct Examination in water of the finely ground material and of suspected fragments picked out under the lens, also a second examination, after the addition of iodine, serves for the identification of the starch grains and some of the tissues. The same portion should afterward be treated with a small drop of alkali, thus rendering the tissues more distinct. Another valuable clearing agent is chloral hydrate solution, in a few drops of which a small portion of the material is allowed to soak for some hours.

Of the characteristic reactions for the detection of particular spices only two need here be mentioned, namely, the change from yellow to brown-red of fragments of turmeric on treatment with ammonia, potash or soda, and the red color imparted to hulls of charlock on heating with chloral.

In the simple manner described most of the adulterants can be detected by one familiar with the elements of the spices themselves and of the adulterants. Treatment with other reagents is sometimes useful but seldom essential.

The Special Methods of preparing the material for microscopic examination described under flour (p. 54), and cereal feeds (p. 59) are applicable for starchy spices, or spices containing an admixture of starchy matter, while those described under oil seeds products (p. 171) are applicable for spices free from starch. The crude fiber process is one of the most useful of these methods. It is, however, seldom necessary to resort to preliminary treatment, as direct examination in water or some other medium, and treatment with reagents on the slide, are usually quite as satisfactory.

Analytical Key to the Common Spices used in Powder Form.

A. Starch present; epidermal tissues with stomata absent.

(*a*) Starch grains minute (2–10 μ), polygonal, forming compact masses.

* Stone cells present, those of the hypodermal layer small, thick-walled.

1. Endocarp of small stone cells (less than 50 μ) with broad cavity. . .Pepper.
2. Endocarp of large stone cells (over 50 μ) with narrow cavity. . . . . . .Cubebs.
3. Endocarp of very large, porous, elongated cells. . . . . .Long Pepper.

** Stone cells absent.

4. Mosaic of brown, thick-walled palisade cells. . . . . .Cardamom.

(*b*) Starch grains medium size (up to 20 μ), rounded, often in small aggregates; hilum distinct.

5. Stone cells and bast fibers present. . . . . Cinnamon [1] and Cassia.
6. Stone-cells present; bast fibers absent; tissues of spermoderm port-wine color. . . . . .Allspice.
7. Neither stone cells nor bast fibers present; tissues of perisperm brown. Nutmeg.

(*c*) Starch grains large (mostly over 20 μ), pear-shaped; hilum excentric; reticulated vessels present.

8. Starch grains perfect; bast fibers present; tissues nearly colorless. . Ginger.
9. Starch grains mostly in formless masses; bast fibers absent; tissues bright yellow, becoming brown-red with alkali. . . . . .Turmeric.

B. Starch absent; epidermal tissues with stomata absent except on calyx of 12 and 13.

10. Palisade cells of speimoderm form a brown mosaic with darker reticulations. Brown Mustard.
11. Palisade cells of spermoderm form a yellow mosaic without reticulations. White Mustard.
12. Epidermal cells of pericarp polygonal, with yellow walls; ground tissue contains yellow or red oil drops. . . . . .Paprika.
13. Same as last, but epidermal cells quadrilateral, in rows. . . . Cayenne Pepper.
14. Epidermis of large elongated cells; ground tissue contains amylodextrine-starch grains (red with iodine). . . . . .Mace.
15. Yellow color soluble in water; pollen grains often present. . . . . . .Saffron.

C. Starch grains absent (except in chlorophyl grains); epidermal tissues with stomata present.

(*a*) Chlorophyl absent.

16. Numerous oil cells; crystal cells in rows beside spiral vessels. . . . . .Cloves
17. Brown jointed oil ducts present. . . . . .Umbelliferous Fruits (p. 551).

(*b*) Chlorophyl present.

* Hairs absent.

18. Epidermal cells with thick, wavy walls. . . . . .Bay Leaf

** Epidermis with simple, jointed and disk-shaped (glandular) hairs.

† Hairs smooth.

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[1] Cassia buds have small starch grains, epidermal hairs, and numerous bundles.

19. Jointed hairs very numerous, long, narrow, pointed................Sage.
†† Hairs warty or smooth.
20. Jointed hairs numerous, long, broad, straight, thin-walled......Marjoram.
21. Hairs very numerous, mostly short, conical......................Thyme.
22. Hairs few, those with joints bent near the end, thin-walled........Savory.

Condimental Cattle and Poultry Foods.

Numerous proprietary mixtures of cereal or oil-seed products, with aromatic substances, simple drugs and other materials, are extensively advertised as food auxiliaries, appetizers and tonics for bovine cattle, horses, swine and poultry. They occupy a place between ordinary cattle foods on one hand and condition powders on the other, and are sold at prices out of proportion to the value of their constituents, with extravagant claims as to their nutritive and curative properties. As foods they are of no greater value than the common feeds of which they are largely composed, while as tonics they are counterparts of numerous patent medicines for human use.

As various aromatic substances are characteristic ingredients, they are properly considered with the spices.

The Constituents may be classed under three heads: (1) food materials; (2) spices, including fenugreek, and (3) drugs.

The food materials include a number of common feeds of greater or lesser value, such as bran and other by-products of wheat, maize meal, gluten meal, linseed meal, bean meal, carob-bean meal, malt sprouts, cocoa shells, etc. With these should be classed salt, ground bone, ground meat, crushed sea shells and ground quartz (the last four being constituents of poultry foods), all of which are useful in the animal economy.

Of the spices fenugreek is probably the most extensively employed, the characteristic odor of many preparations being due to this constituent. Ginger, cayenne pepper and mustard hulls are also common ingredients, while anise and fennel are stated to be present in some mixtures.

The drugs are partly vegetable and partly mineral.

The bitter taste of most of the mixtures is due to ground gentian root, the cheapest of the bitter drugs, although wormwood is sometimes employed. Charcoal serves not only as a remedy, but also to give the mixture a gray color, thus concealing other constituents. Licorice, lobelia, bloodroot, elecampane, and other drugs are less often used.

Among the mineral drugs reported by analysts are sulphur, Epsom salts (magnesium sulphate), Glauber's salts (sodium sulphate), potassium chlorate, and Venetian red (iron oxide).

Methods of Examination.

Preliminary Examination. The hints given under cereal cattle foods (p. 59), oil-seed products (p. 170), and spices (p. 496) apply also to condimental foods.

Fenugreek, ginger, cayenne pepper, and umbelliferous seeds are characterized by their odor and taste; gentian, common salt, and other salts by their taste; charcoal and Venetian red by their color; ground quartz by its gritty nature.

Vegetable constituents can often be picked out for microscopic examination, and small crystals of Epsom and Glauber's salts, lumps of sulphur, fragments of sea shells and other mineral constituents, for chemical tests.

Chemical Examination. *Qualitative Tests* are made for chlorine (common salt), sulphuric acid (Epsom and Glauber's salts), magnesia (Epsom salts), carbonic acid (calcium carbonate), lime (calcium carbonate and phosphate), phosphoric acid (calcium phosphate), iron (Venetian red), sulphur, etc.

These tests can all be made on quite small particles picked out from the material. Those soluble in water are conveniently dissolved in a minute drop of water and a drop of the reagent added from a stirring rod. In this way we can detect in fragments weighing less than a milligram, chlorine by silver nitrate, sulphuric acid by barium chloride, magnesia by sodium phosphate. Carbonic acid of calcium carbonate is recognized by the effervescence with dilute hydrochloric acid, while lime is detected in the same portion, after making alkaline with ammonia, on addition of ammonium oxalate. The phosphoric acid of bone in a nitric acid solution gives on heating with ammonium molybdate solution a bright-yellow precipitate. Sulphur burns with a blue flame giving off sulphurous vapors. Iron is best detected in the ash by its red-brown color and the red-brown precipitate of ferric hydrate obtained after dissolving in hydrochloric acid and addition of ammonia. Powdered charcoal is recognized by the fact that it is not bleached by boiling with aqua regia or a mixture of potassium chlorate and nitric acid, also by the gray color of the crude fiber obtained by the usual process.

Quantitative Analyses. The usual proximate constituents (water, ash, protein, crude fiber, nitrogen-free extract, and fat, or rather ether extract) are determined, and if mineral drugs are present their constituents are also quantitatively determined. Carbonic acid is determined in the original material: Chlorine in the water solution; sulphuric acid, and magnesia, either in the water solution of the original material or the acid solution of the ash; phosphoric acid, calcium oxide and iron oxide in the acid solution of the ash, and sulphur in the ether extract after oxidation to sulphate.

Microscopic Examination. The special methods described on pp. 497 may be used in preparing the material for examination, although as a rule the finely ground material and fragments picked out under a lens may be suitably examined in water, and again after treatment with iodine, alkali, or other reagents.

Cereal products are recognized by the characteristic starch grains and the tissues of the bran and chaff; starchy leguminous seeds by the ellipsoidal starch grains with elongated hilum, also by the tissues of the spermoderm; linseed meal by the rectangular pigment cells with deep brown contents, and yellow-brown fragments consisting of the superimposed fibers and subepidermal cells; cottonseed meal by the yellow cell-contents of the embryo, the brown resin particles becoming red with sulphuric acid, and the remarkable elements of the black spermoderm.

Fenugreek is usually present in relatively small amount, and it is often a tedious search to find fragments showing the characteristic pointed palisade cells and the broad column cells with ribs. This is especially true if linseed meal is present, as the spermoderm of this seed is also of a brown color. Of some aid in the search is the bright-yellow color imparted to the spermoderm by alkali.

The most characteristic elements of umbelliferous seeds are the oil ducts.

Cayenne is identified by the characteristic rectangular cells of the epicarp, with thick yellow walls, the intestine cells of the spermoderm, and the yellow or red oil drops.

The chief elements of ginger are the large pear-shaped starch grains with excentric hilum, although the reticulated vessels and long bast fibers occur in small amount.

Gentian, unfortunately, has no characteristic tissues, but in the absence of ginger the reticulated vessels, coupled with the bitter taste, furnish an indication of its presence.

Charcoal in powder form appears under the microscope as black opaque particles, which are not affected by any of the ordinary reagents.

These particles may be found unchanged in the crude fiber obtained by the ordinary acid and alkaline treatment, also in the residue after bleaching, as already described.

PIPERACEOUS FRUITS (*Piperaceæ*).

Black pepper, long pepper, and cubebs are single-seeded berries with the reserve material largely in the bulky perisperm.

Hypodermal stone cells of the usual type are found in the pericarp of all three berries, while the endocarp of each is characteristic of the species, consisting in cubebs of several layers of large stone cells, in black pepper, of a single layer of small cells thickened in the inner part (beaker cells), and in long pepper of large elongated cells with moderately thick walls. In all three species very small, polygonal starch grains fill the cells of the perisperm. The largest grains occur in long pepper.

PEPPER.

Both the black and the white peppercorns of commerce are berries of *Piper nigrum* L., a climbing perennial indigenous to Malabar and Travencore, and cultivated in Sumatra, Siam, Borneo, Java, Ceylon, the Philippines, and tropical America.

The vine reaches a length of 15 meters, and attaches itself to trees, rocks, or trellises by means of aerial roots thrown out from the joints. The inflorescence is in spikes up to 10 cm. long, either terminal, or opposite leaves, bearing 20–50 flowers, each nearly hidden from view by two bracts. The flowers appear in May or June, and the fruit, a one-seeded berry, ripens six months later, changing during ripening from green to red and finally to yellow.

Black peppercorns are the green berries dried without shelling, either in the sun or over fires. Owing to the shrinking of the meat during drying, the black or green shell, consisting of pericarp and spermoderm, is strongly wrinkled.

White peppercorns are the berries, picked usually when fully ripe, which have been freed from the outer shell. The process commonly employed consists in soaking the berries in salt water or lime water, rubbing off the shell either with the fingers or by machinery, and drying;

but in some regions the shell is removed dry. The corns are of a light gray color, and while not so pungent as black pepper, have a finer flavor.

Pepper is a notable example of a seed with reserve material almost entirely in the perisperm (Fig. 428). This perisperm forms the body of the seed, and has a cavity in the center one mm. or more in diameter and a smaller cavity in the apex containing traces of embryo and endosperm. The outer portion of the perisperm is horny, the inner portion floury.

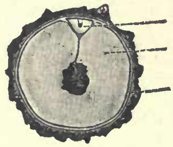

FIG. 428. Black Pepper (*Piper nigrum*). Longitudinal section of fruit. *E* endosperm; *N* perisperm; *FS* pericarp and spermoderm. ×3. (MOELLER.)

The grades of pepper on the market are designated according to their places of growth, or oftener their ports of shipment, as Singapore, Siam, Tellicherry, Trang, Lampong, Acheen, Penang, etc. Singapore black pepper, one of the best grades, is fire-dried, and consequently has a smoky odor and taste. Most of the other peppers, being sun-dried on the ground, do not have this quality, but are more or less contaminated with stems, earth, small stones, and in the case of Acheen, the poorest sort, with empty and light-weight kernels. Acheen pepper is sifted free of coarse shells before shipment and separated into grades A, B, C, D, according to the specific gravity; but the empty or light-weight kernels are more or less broken up during the sea voyage and handling, so that the product is invariably contaminated with more or less shells. Penang white pepper is coated with a gray substance consisting chiefly of carbonate of lime.

The characteristic constituents of pepper are: (1) Piperine, an inert, non-volatile, crystalline substance, (5–8 per cent); (2) piperidine, a volatile alkaloid; (3) clavacin, a pungent resin; and (4) an aromatic volatile oil. Starch varies up to 40 per cent in black pepper and up to 60 per cent in white pepper.

HISTOLOGY.

Black peppercorns, sectioned either dry or after soaking in water, serve for the study of all the elements of the fruit; white peppercorns for all the elements but the outer pericarp. Clearing of the tissues may be effected either by heating with dilute alkali, or better by soaking in Javelle water.

Pericarp (Figs. 429 and 430). To the naked eye the pericarp in black pepper is black or gray-black throughout, but in white pepper all that remains of the pericarp, namely the inner layer, is light gray.

1. *The Epicarp* (*ep*) consists of polygonal cells (15–30 μ) and occasional stomata, covered by a cuticle 5 μ thick. In the dried berries the contents are dark brown or black.

2. *Hypoderm* (*ast*). Small thin-walled cells, intermingled with strongly thickened, often radially elongated, porous, yellow stone cells, form the hypodermal layer. Both forms of cells often contain a dark-brown material, which takes on a reddish color with alkali. The stone cells vary greatly in size and are among the most conspicuous elements of the fruit, but are of course absent in white pepper, while pepper shells, removed in the preparation of white pepper, contain them in extraordinarily large numbers.

3. *Outer Mesocarp.* The mesocarp is differentiated into four more or less distinct layers. In the outer layers most of the cells are of moderate size, and contain minute starch grains or chlorophyl; but here and there larger cells with suberized walls contain oil or resin. This is the innermost of the layers removed in preparing white pepper.

4. *Bundle Layer* (*fv*). In the next layer, consisting of smaller, more or less compressed cells, ramify the fibro-vascular bundles.

5. *Oil Cells* (*p*). An interrupted layer of large cells with suberized walls and oily contents is evident in cross-section.

6. *An Inner Mesocarp* of thin-walled but porous cells completes the pulpy part of the pericarp.

7. *Endocarp* (*ist*). Beaker Cells, so called because of their thickened, sclerenchymatized inner and radial walls, form the inner stone cell layer or endocarp. As seen in cross-section, they are horseshoe-shaped with distinct pores. Surface preparations are also characteristic, the double porous walls being thinner than in the stone cells of the outer layers.

Spermoderm (Figs. 429 and 430). This forms a thin layer of little diagnostic importance.

1. *Outer Epidermis* (*is*). Vogl and some other authorities consider the elongated cells of this layer as belonging to the spermoderm; Tschirch and Oesterle, however, who have studied its development, believe that it is a portion of the pericarp. Its connection with the spermoderm is best seen in the vicinity of the micropyle, where the cells are largest and thickest-walled. Over the body of the seed they are much compressed and are scarcely evident except after heating with alkali, or bleaching with Javelle water, washing in dilute acetic acid and staining. This latter treatment not only causes the compressed cells to assume their original shape, but also greatly swells the walls.

2. *Middle Coat.* This consists of one or two layers of elongated cells similar to those of the epidermis.

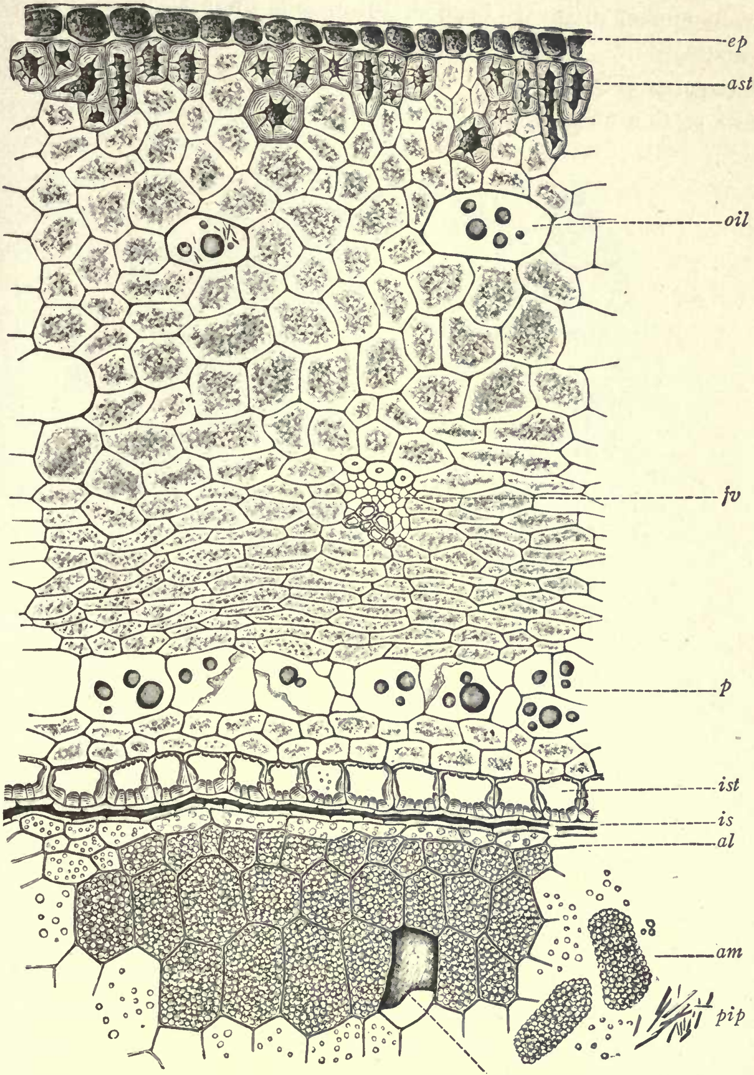

FIG. 429. Black Pepper. Cross section of outer layers of fruit. Pericarp consists of *ep* epicarp, *ast* hypodermal stone cells, *oil* outer mesocarp with oil cells, *fv* bundle zone, *p* oil cells, and *ist* endocarp; spermoderm consists of *is* outer epidermis, and inner layers (not shown); perisperm consists of *al* aleurone cells, *am* starch masses, *res* resin cells, and *pip* piperin crystals. (MOELLER.)

3. *Pigment Layer.* Owing to the dark-brown tannin substance, the elongated cells of this layer are conspicuous both in cross section and

surface view, although their cell-structure is not clearly seen except after treatment with alkali or some other reagent. Under favorable conditions the walls appear distinctly beaded. Iron salts impart a blue color to the contents.

Perisperm (Figs. 429 and 430). 1. *Hyaline Layer.* This is evident in cross section as a hyaline band inclosing not only the inner layers of

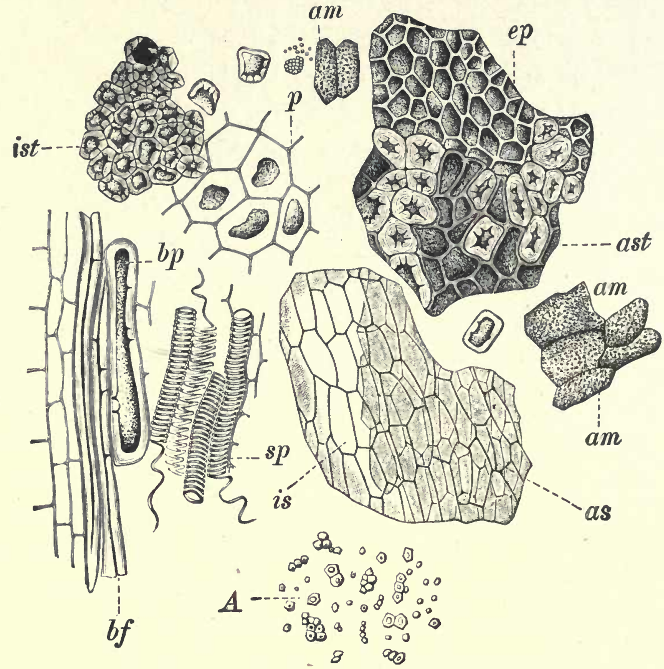

FIG. 430. Black Pepper. Elements of powder. *ep* epicarp; *ast* hypodermal stone cells; *bf* bast fibers; *bp* bast sclerenchyma; *sp* vessels; *p* oil cells; *ist* endocarp; *is*, *as* layers of spermoderm; *am* starch masses. ×160. *A* starch grains, ×600. (MOELLER.)

the perisperm, but also the embryo and endosperm at the end of the seed. As it does not show evidences of being pierced by the micropyle, it is here classed with the perisperm. Evidences of the cellular structure appear on treatment of cross sections with alkali. In surface view the cells are elongated polygonal with thin walls.

2. *Aleurone Cells* (*al*). Macroscopic examinations of a kernel cut in half show that the outer portion is horny, while the inner portion, surrounding the central cavity, is mealy. If cross sections are treated with iodine solution and examined under the microscope, it is evident that the cells of the two or more outer layers are small and contain aleurone grains, but no starch.

3. *Starch Cells* (*am*). The inner portion of the perisperm consists of large, radially elongated cells, up to 150 μ long, filled with masses of minute starch grains embedded in proteid matter. The starchy contents of the inner cells separate as compact masses conforming to the shape of the cells, in which are evident not only the individual grains, but sometimes also oval aggregates of grains such as occur in rice and oats. Pepper starch grains are among the smallest in the vegetable kingdom, being usually 2–4 μ in diameter and never exceeding 6 μ. They are polygonal or rounded and have an evident hilum. Strikingly different from the polygonal cells containing aleurone grains and starch are the rounded resin cells (*res*) distributed here and there among these. In these are contained yellow globules of oil, also lumps of resinous matter, and often needle-shaped crystals of piperin (*pip*). These latter are seen in greater numbers after mounting in alcohol, allowing the alcohol to evaporate slowly, and remounting in water. The piperin is soluble in alcohol and ether, but insoluble in water. If sections are placed in a drop of concentrated sulphuric acid a deep-red solution is obtained.

Endosperm and Embryo are minute and are of no diagnostic importance.

DIAGNOSIS.

Black Pepper, although prepared from the green berry, contains all the microscopic elements of the fruit in practically full development. Of greatest importance in identification are the outer stone cells (Fig. 430, *ast*), the beaker cells (*ist*), and the masses (*am*) consisting of minute starch grains (*A*). Sulphuric acid dissolves the piperin to a deep-red solution, but other members of the genus give the same reaction, and its value is further impaired by the fact that similar red solutions are obtained with cottonseed and other products.

Ground Black Pepper, since it contains both the dark tissues of the pericarp and spermoderm and the light-colored starchy perisperm, is of a dark-gray or brown-gray color. It is more pungent than white pepper, although the natural flavor is often mingled with an earthy or, in the case of fire-dried varieties, with a smoky flavor.

The adulterants of pepper are probably more numerous and varied than those of any other food product, not excepting coffee. They include linseed meal, buckwheat hulls, nutshells (cocoanut, walnut, almond, hazelnut, etc.), mustard hulls, screenings, charcoal, cereal products, peas and other leguminous seeds, poppy seeds, olive stones, sawdust, cocoa shells, pepper hulls, mineral diluents and colors, exhausted pepper, exhausted spices,—in fact any waste material with a not too pronounced flavor that can be easily reduced to a powder. It is a common practice to mix light- and dark-colored adulterants in order to better imitate the color of the genuine product, and also to add a little cayenne pepper to give pungency to fraudulent mixtures which otherwise would be nearly tasteless. Nutshells, sawdust, buckwheat hulls, cocoa shells, pepper shells, and other fibrous or woody materials have much higher amounts of crude fiber but less starch than genuine pepper, while the reverse is true of most starchy adulterants. The ether extract of pepper consists largely of piperin, a nitrogenous substance, whereas the extract of some of the adulterants contains no appreciable amounts of nitrogen. As Acheen pepper contains a considerable amount of loose shells and consequently a high percentage of ash and fiber, it is frequently not possible either by microscopic examination or chemical analysis to distinguish this grade in powder form from a better grade adulterated with pepper shells. Legal standards of composition are designed to exclude pepper unfit for consumption, whether ground from a very low grade of berry or willfully mixed with shells.

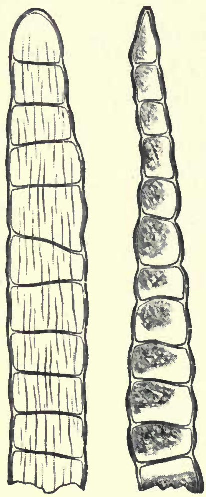

FIG. 431. Black Pepper. Hairs from spindle. (MOELLER.)

White Pepper is usually prepared from the ripe berry, the globular corns, although deprived of the outer layers of the pericarp, being usually somewhat larger than black peppercorns and free from wrinkles. They are light gray, lusterless, and delicately veined with the pericarp bundles. Penang white pepper is coated with a gray substance consisting largely of carbonate of lime. The portion of the pericarp removed consists of the epicarp, the hypodermal stone cells, and the outer mesocarp up to the bundles. Except for these layers, the microscopic elements are the same as in black pepper, any difference due to degree of ripeness being too slight for detection. As the powder is of a light-gray color, the adulterants used are light-colored materials, such as wheat flour, maize meal, ground rice, buckwheat flour, and various other cereal products, ground peas and other legumes, white poppy seeds, ground olive stones, cayenne pepper, also gypsum and other white mineral substances. Cereal adulterants do not greatly alter the percentage of starch, but are readily detected by the characters of the starch granules and the tissues. Olive stones increase the crude fiber and diminish the starch. White and black pepper are both characterized by the nitrogen of the ether extract, due to piperin.

Decorticated White Pepper, consisting of peppercorns deprived of all the coats of the pericarp and spermoderm, is made from black pepper in machines of special construction. The powder is light yellow, of a delicate fragrance, and contains, in appreciable amount, only the elements of the perisperm. Because of the lack of other elements, adulteration is the more readily detected.

Pepper Shells, obtained in the manufacture of white pepper, being cheap, pungent, and difficult of detection, are frequently mixed with ground black pepper. They show a preponderance of stone cells under the microscope, and contain a high percentage of fiber and ash, the latter being due largely to adhering dirt.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Berg (3); Blyth (5); Flückiger (11); Greenish (14); Hanausek, T. F. (10, 16); Hassall (19); Leach (25); Macé (26); Moeller (29, 30, 31, 32); Planchon et Collin (34); Schimper (37); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (43, 45).

ANDOUARD: Falsification du poivre par le Galanga. Jour. pharm. chim. 1890, **21**, 585.

BEYTHIEN: Ueber Gewürze. Ztschr. Unters. Nahr.-Genussm. 1903, **6**, 957.

BERTARELLI: Verfälschung von weissen Pfefferkörnern. Atti della Società Piemontese d'Igiene. 1900–01, **7**.

BERTSCHINGER: Künstliche Pfefferkörner. Schw. Woch. Chem. Pharm. 1901, **39**, 215.

BONNET: Du poivre et de ses falsifications. Thèse E. de Ph. de Paris. 1886, 19.

BROWN: On Another New Pepper Adulterant. Analyst. 1887, **12**, 89.

BRUNOTTI: Des fruits utiles des Pipéritées. Thèse d'agrégation. Concours, 1889, 31.

CHEVREAU: Recherche de la falsification du poivre par le grignon d'olives au moyen des sels d'aniline. Rep. de Pharm. 1889, **17**, 203.

DAELS: Falsification du poivre blanc en poudre. Journ. Pharm. d'Anvers. 1904, **60**, 1.

GILLET: Méthod nouvelle pour reconnaître la falsification des poivres par addition de grignons d'olives. Bull. soc. chim. 1888, **50**, 173.

GLADHILL: Commercial Pepper. Amer. Jour. Pharm. 1904, **76**, 71.

GRIMALDI: Sopra una falsificazione del pepe in grani. Staz. sperim. agrar. Ital. 1901, **34**, 705.

HANAUSEK, E.: Schwarzer Tellicherrypfeffer. Ztschr. Nahr.-Unters. Hyg. 1888, **2**, 5.

HANAUSEK, T. F.: Ueber die Harz- und Oelräume in der Pfefferfrucht. Sep.-Abdr. aus Programm der k. k. Staatsrealschule am Schottenfelde, Wien, 1886.

HANAUSEK, T. F.: Ueber die Matta. Ztschr. Nahr.-Unters, Hyg. 1887, **1**, 24.

HANAUSEK, T. F.: Künstlicher Pfeffer. Ztschr. allg. österr. Apoth.-Ver. 1887, **12**, 180.

HANAUSEK, T. F.: Im Budapester Handel beobachtete Pfefferfälschungen. Ztschr. Nahr.-Unters. Hyg. 1889, **3**, 33, 58.

HANAUSEK, T. F.: Künstliche Pfefferkörner. Ztschr. Nahr.-Unters. Hyg. 1889, **3**, 31.

HANAUSEK, T. F.: Die Pfefferfruchtspindeln. Ztschr. Nahr.-Unters. Hyg. 1889, **3**, 59.

HANAUSEK, T. F.: Ueber einige, gegenwärtig im Wiener Handel Vorkommende Gewürzfälschungen. Ztschr. Nahr.-Unters. Hyg. 1894, **8**, 95.

HANAUSEK, T. F.: Ueber den schwaızen Pfeffer von Mangalore. Ztschr. Unters. Nahr.-Genussm. 1898, **1**, 153.

HANAUSEK, T. F.: Ueber eine neue Pfefferfälschung. Ztschr. Unters. Nahr.-Genussm. 1898, **1**, 490.

HANAUSEK, T. F.: Olivenkerne und ihre Erkennung im Pfefferpulver. Pharm. Centralh. 1885, **25**, 261.

HÉBERT: Moyen facile et rapide de reconnaître la falsification du poivre. Journ. pharm. chim. 1891, **23**, 283.

JUMEAU: Note sur les falsification du poivre en poudre. Journ. pharm. chim. 1889, **20**, 442.

KUNDRAT: Das neueste Verfälschungsmittel für Pfeffer. Ztschr. Nahr.-Unters. Hyg. 1895, **9**, 104.

LANDRIN: Falsification du poivre a l'aide des grignons d'olive. Jour. Pharm. **10**, 194.

MAINSBRECQ: Falsification du poivre. Bull. Assoc. Belge Chim. 1901, **15**, 335.

MARTELLI: Nachweis der Verfäschungen des gemahlenen Pfeffers. Ztschr. Nahr.-Unters. Hyg. 1895, **9**, 205.

MENNECHET: Sur une falsification du poivre par les fruits du *Myrsine Africana* L. et *Embelia ribes* Burm. Jour. pharm. chim. 1901, **14**, 557.

MEYER, ARTHUR: Die mikroskopische Untersuchung von Pflanzenpulver, speziell über den Nachweis von Buchweizenmehl in Pfefferpulver und über die Unterscheidung des Maismehls von dem Buchweizenmehl. Arch. Pharm. 1883, **21**, 911.

MOELLER: Ein neues Verfälschungsmittel für Pfeffer. Rep. anal. Chem. 1886, 409.

MOELLER: Matta. Pharm. Post, 1886, 365.

MOLINARI: Nachweis von Olivenkernen im Pfeffer. Rev. chim. anal. appl. 1898, **6**, 6.

MORPURGO: Delle Spezie. Trieste, 1904.

NESTLER: Ueber Verfälschungen von Macis, Pfeffer und Safran. Ztschr. Unters. Nahr. Genussm. 1903, **6**, 1033.

NEUSS: Zur Pfefferuntersuchung. Pharm. Ztg. 1885, **30**, 26.

PABST: Nachweis einer Pfefferfälschung durch Olivenkerne mittels Anilinsalzen. Rev. internat. falsificat. 1889, **3**, 8.

PABST: Recherches des grignons d'olives dans le poivre. Journ. pharm. chim. 1890, **21**, 645.

PAOLINI: Sopra una nuova falsificazione del pepe comune. Staz. sperim. agrar. Ital. 1901, **34**, 966.

PEINEMANN: Beiträge zur pharmakognostischen und chemischen Kenntniss der Cubeben und der als Verfälschung derselben beobachteten Piperaceenfrüchte. Arch. Pharm. 1896, **234**, 204.

PLANCHON: Note sur le poivre et les grignons d'olive. Jour. pharm. chim. 1885, **11**, 641.

RAU: Ueber neuere Verfälschungen des gemahlenen Pfeffers. Ztschr. öffentl. Chem. 1900, **6**, 243.

RAUMER UND SPAETH: Fälschungen von Gewürzen und anderen Nahrungsmitteln. Ztschr. Unters. Nahr.-Genussm. 1902, **5**, 409.

RIMMINGTON: Pepper Adulteration and Pepper Analysis. Analyst. 1888, **13**, 81.
SPAETH: Ueber ein neues Verfälschungsmittel des gemahlenen Pfeffers. Forschber. Lebensm. Hyg. 1893, **1**, 37.
TEYXEIRA E FERRUCCIO: Pepe naturale ed artificiale. Boll. Chim. Farm. 1900, **39**, 534.
UHL: Zur Untersuchung des Pfeffers. Forschungsb. Lebensm. Hyg. 1886, 127.
WENDER: Kunstpfeffer. Ztschr. allg. österr. Apoth.-Ver. 1887, **25**, 145.

LONG PEPPER.

Two species yield the long pepper of commerce, *Piper officinarum* DC., grown in Java, the Philippines, India, and other parts of the East and *P. longum* L., sparingly cultivated in India, the former species being by far the most important.

The inflorescence is in a dense spike which ripens into a dark-gray or black compound elongated catkin-like fruit consisting of numerous consolidated berries. The surface bears spiral rows of small protuberances, which are the exposed outer ends of the individual berries. Each compound fruit is 2–6 cm. long and 4–7 mm. broad in the case of *P. officinarum*, somewhat shorter and thicker in the case of *P. longum.*

HISTOLOGY.

After soaking over night in water, the compound fruit is in excellent condition for cutting longitudinal and transverse sections, corresponding respectively to transverse and longitudinal sections of the individual berries. These sections should be soaked in Javelle water to swell out the layers of the spermoderm and stained.

Pericarp. Owing to the consolidation of the lower portions of adjoining pericarps, the epicarp and hypoderm are developed only on the outer end of each individual.

1. *The Epicarp* is of polygonal cells with no distinctive characters.

2. *Hypodermal Stone Cells* do not form a continuous layer, but are scattered here and there through the outer cell layers. A few of these stone cells also occur in the middle layers of the consolidated pericarp tissue.

3. *The Outer Mesocarp,* composed of parenchyma cells (no oil cells), contains numerous small starch grains and traces of chlorophyl.

4. *Inner Mesocarp.* The mesocarp cells show little differentiation up to the inner two or three layers, where they grade into the sclerenchymatized, thickened, porous cells of the endocarp. This transition is

brought out by safranin after bleaching with Javelle water. The inner layers contain no starch and are none of them typical oil cells.

5. *Endocarp.* Most characteristic of all the tissues are the large, longitudinally elongated, porous, sclerenchyma cells of this layer, which are radically different from the small beaker cells of pepper or the strongly thickened stone cells of cubebs. They form striking objects in tangential or surface sections, especially after staining, and in transverse or longitudinal section are conspicuous because of the thickened inner walls and the decrease in thickness of the radial walls from within outward.

6. *An Inner Layer* of beaded cells with slightly undulating walls may be found by examining the inner surface or the fragments obtained by scraping. These cells or their inner portions also occur on the spermoderm. It is probable that this layer belongs to the pericarp and corresponds to the cells Tschirch and Oesterle find in unripe black pepper. Those cells of ripe black pepper which they regard as these pericarp cells in a later stage of development appear to belong to the spermoderm.

Spermoderm. Cross-sections show little detail until treated with Javelle water, after which the structure is clearly analogous to that of black pepper and cubebs.

1. *The Outer Epidermis,* as may be seen after treating either cross-sections or surface preparations as described, has swollen outer and radial walls even more striking than those of black pepper and cubebs. Surface preparations show that the cells are longitudinally elongated, 12–20 μ broad.

2. *The Middle Coat,* consisting mostly of one or two layers, but at the base of a number of layers, has cells with swollen walls much like those of the outer epidermis.

3. *The Pigment Cells* are readily found in transverse or surface sections, and after removal of the pigment by Javelle water, are seen to be distinctly reticulated, the radial walls appearing beaded in surface view.

Perisperm. *1. Hyaline Layer.* The swollen, structureless outer membrane, the so-called "hyaline layer" regarded by many authors as the inner spermoderm, is the same as is found in pepper and other members of the genus.

2. *The Aleurone Cells* are small and contain little or no starch.

3. *Starch Parenchyma,* with no evidence of oil cells, form the inner perisperm. The polygonal or rounded starch grains vary from 2–10 μ,

being usually about 4 μ, or a little larger than those of black pepper. Concentrated sulphuric acid produces a deep carmine color due to piperin.

DIAGNOSIS.

Long pepper has been repeatedly detected by English analysts as an adulterant or substitute for black pepper. It is distinguished by the somewhat larger starch grains, and especially by the large, elongated, moderately sclerenchymatized cells of the endocarp, and the absence of beaker cells and oil cells. The powder also has a distinctive odor.

CUBEBS.

Cubebs, the fruit of a vine (*Piper Cubeba* L.), although properly classed with the drugs, are of interest to the food microscopist because they are analogous in structure to the fruits of black and long pepper. At the present time cubebs are seldom used as spices, but the exhausted berries are sometimes mixed with black pepper as an adulterant.

The plant grows in Sumatra, Java, and other islands of the East Indies.

The dark-brown, wrinkled berry is about the same size as a black peppercorn, which it further resembles in morphological structure. Unlike black pepper, the berry is borne on a stem 6–8 mm. long, and the seed, often only partially developed, is not united with the sides of the pericarp. Among the constituents are volatile aromatic principles, and cubebin, a non-volatile crystalline substance related to piperin.

HISTOLOGY.

Although cubeb and pepper berries are analogous in microscopic structure, certain of the elements are strikingly different.

Pericarp. 1. *The Epicarp* of small polygonal cells is hardly distinguishable from the corresponding coat of pepper, although the cell-contents are usually of a lighter color.

2. *The Hypodermal Stone Cells*, 24–40 μ in diameter, are not usually radially elongated and are for the most part in a single layer.

3. *The Outer Mesocarp* is composed of parenchyma cells containing small starch granules (2–6 μ) and oil cells containing crystals of cubebin in addition to fatty matter.

4. *Compressed Cells* form that portion of the mesocarp through which ramify the bundles.

5. *The Inner Mesocarp* of several layers of parenchyma cells interspersed with oil cells contains no starch grains.

6. *The Endocarp,* or inner stone-cell layer, is much more strongly developed than the corresponding beaker cells of pepper. It consists of one or more layers of large isodiametric or radially elongated stone cells (often 80 μ) with walls thickened on all sides.

7. *An Inner Layer* of irregular cells lies between the endocarp and spermoderm. In cross-section this layer is scarcely distinguishable, but on examining the inner surface of the pericarp or the outer surface of the spermoderm, the thin beaded side walls are clearly evident.

Spermoderm. Cross-sections show the same number of layers as is found in black pepper.

1. *Outer Epidermis.* The longitudinally elongated cells, often 150–200 μ long and 25–50 μ wide, are much larger than any of the elements of the spermoderm of pepper. In surface view they are recognized, after heating with alkali or after bleaching with Javelle water and staining with safranin, by their size, more or less rectangular form, and swollen brown walls (double walls 10–15 μ).

2. *A Middle Coat* of one or two cell layers is present in most parts of the seed. The narrow cells are elongated and the walls are swollen after treatment with the reagents named.

3. *Inner Epidermis.* Irregular cells, often longitudinally elongated, with walls of even thickness or faintly beaded, form a dark-brown pigment layer not unlike the corresponding cells of both black and long pepper. Like these latter, as may be seen in longitudinal section, they are tabular except near the micropyle, where they are radially elongated.

Perisperm. 1. *A Hyaline Layer* forms a thickened, apparently structureless membrane enclosing the perisperm, the embryo, and endosperm; the two latter being situated in a small hollow at the apex.

2. *Aleurone Cells* constitute several outer layers.

3. *Starch Parenchyma* intermingled with yellow-green oil cells make up the heart of the perisperm. The starch grains are rounded or polygonal, 3–12 μ in diameter, and are closely packed in the cells. Sections mounted in concentrated sulphuric acid take on a deep carmine color.

DIAGNOSIS.

The powder is distinguished from ground pepper by the larger starch grains, the presence of large stone cells in place of beaker cells, and the large cells of the middle spermoderm. The elements of the stem are also present, the large sclerenchymatized bast parenchyma being especially noteworthy.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Berg (3); Meyer, A. (27); Moeller (31, 32); Planchon et Collin (34); Tschirch u. Oesterle (40).

DEWÈRE: Recherches sur le cubèbe, etc. Ann. Soc. roy. sci. méd. nat. de Bruxelles, 1894, **3**.

HARTWICH: Weitere Beiträge zur Kenntniss der Cubeben. Arch. Pharm. 1898, **236**, 172.

HARTWICH: Cubeba Real-Enzykl. d. ges. Pharm. 2 Aufl. IV, 1905.

PEINEMANN: Beiträge zur pharmakognostischen und chemischen Kenntniss der Cubeben und der als Verfälschung derselben beobachteten Piperaceenfrüchte. Arch Pharm. 1896, **234**, 204.

VOGL: Falsche Cubeben. Pharm. Centralh. 1895, **36**, 11.

WEVRE: Ueber Cubeben und ihre Verfälschungen. Apoth.-Ztg. 1895, **10**, 345.

SOLANACEOUS FRUITS (*Solanaceæ*).

Cayenne pepper and paprika, the two species of capsicum used as spices, are characterized by the sclerenchyma cells of the epicarp and endocarp, the yellow or red oil drops of the mesocarp, and the curious intestine cells of the spermoderm. Starch in appreciable amount is absent.

PAPRIKA.

Various species of the genus *Capsicum* yield pungent fruits widely different in form, size, and color, which serve both for seasoning food and in medicine. Throughout the Continent, the large fruit of *C. annuum* L., known as paprika, also as Hungarian, Spanish, Turkish, or Indian pepper, are chiefly used; in England and America the small but exceedingly pungent peppers of *C. fastigiatum* Bl. and *C. frutescens* L., are more highly prized for grinding, although peppers of numerous varieties of *C. annuum* are grown for pickling either green or ripe.

Paprika is cultivated in Hungary, Spain, Italy, France, and Turkey. The red or yellow shining fruit, appearing as if lacquered, is inflated, 5–10 cm. long, and from half to three-fourths as broad. The pericarp, even before drying, is but a few millimeters thick, the bulk of the fruit consisting of the fruit cavity divided at the base into two or three compartments. Numerous flattened seeds (3–5 mm.), shaped much like the human ear, are borne in the lower part of the fruit on the central placenta, and in the upper part on the partitions which here only extend part way to the center. The embryo, with a long radicle and still longer, narrow cotyledons, is coiled within the endosperm in such a way that the radicle points toward the elongated (2 mm.) hilum. The hollow stem, 3–4 mm. in diameter, and the small, green, pentagonal or hexagonal calyx are attached to the dried fruit as found on the market.

HISTOLOGY.

Any of the large garden peppers or the dried whole paprika fruit may be employed for studying the histology.

The Fruit Stem (Fig. 432) has an epidermis and outer cortical layer, like the corresponding layers of the calyx in structure. Wood elements

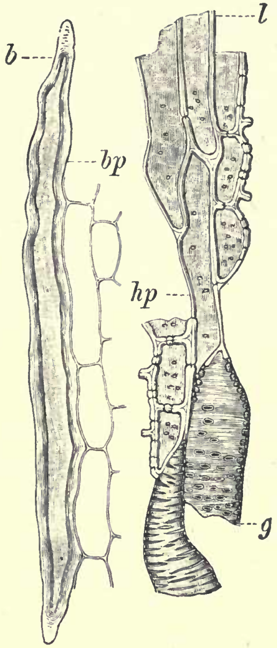

FIG. 432. Paprika (*Capsicum annuum*). Elements of stem. *b* bast fiber; *bp* bast parenchyma; *l* wood fibers; *hp* wood parenchyma; *g* pitted vessels. ×160. (MOELLER.)

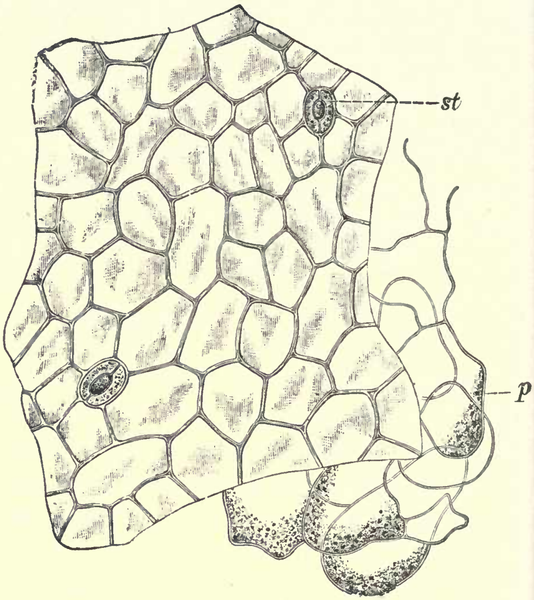

FIG. 433. Paprika. Surface view of calyx showing outer epidermis with *st* stoma, and *p* spongy parenchyma. ×160. (MOELLER.)

form a continuous hollow cylinder surrounded by a narrow, interrupted bast ring. The elements of the wood, consisting of pitted and reticulated vessels, libriform fibers, and wood parenchyma, are strongly thickened, while the bast contains a characteristic element in the form of broad (up to 50 μ), flexible fibers with wide cavities.

Calyx. Sections of the dry material swell considerably in water, displaying an uncommonly large-celled tissue.

1. *The Outer Epidermis* (Fig. 433), as seen in surface view, consists of large, flat, moderately thick-walled, sharply-polygonal cells, with a few stomata.

2. *Mesophyl* (Fig. 434). Adjoining the outer epidermis is a single layer of cells in close contact with each other, and a similar layer adjoins the inner epidermis, but in the middle layers the cells are larger and thinner-

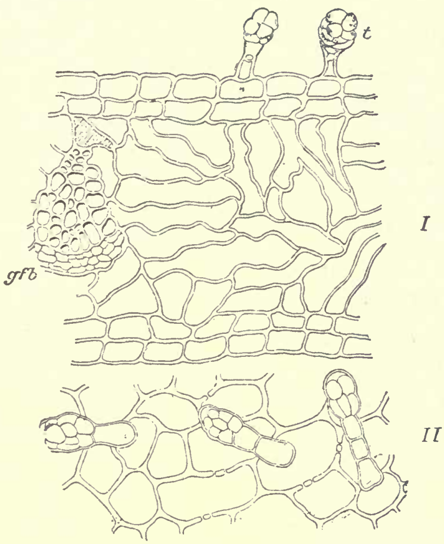

FIG. 434. Paprika. *I* cross section of calyx showing *t* hairs of inner (upper) epidermis and *gfb* fibro-vascular bundle. *II* inner (upper) epidermis of calyx, in surface view. (TSCHIRCH and OESTERLE.)

walled, forming a spongy parenchyma. Through the inner layers run the fibro-vascular bundles. Chlorophyl is present in the hypodermal layers, but not in the spongy parenchyma.

3. *The Inner Epidermis* (Fig. 434) has moderately large cells with wavy walls but no stomata. Characteristic are the peculiar glandular hairs. These are short, two or more celled, with single or compound end cells containing red-brown resinous bodies. Noteworthy is the fact that they are not, like most hairs, simply epidermal cells prolonged beyond the surface, but they spring from the middle of much broader cells after the manner of root-hairs.

Pericarp, Outer Wall. In cutting sections, the material should be held between pieces of pith or embedded in paraffine and care taken to avoid tearing away the inner layers.

1. *Epicarp* (Fig. 435, *epi;* Fig. 436). This layer, in cross-section, has a cuticularized and thickened outer wall 15–20 μ thick. In surface view the cells are polygonal, moderately thin-walled (double walls 3–8 μ)

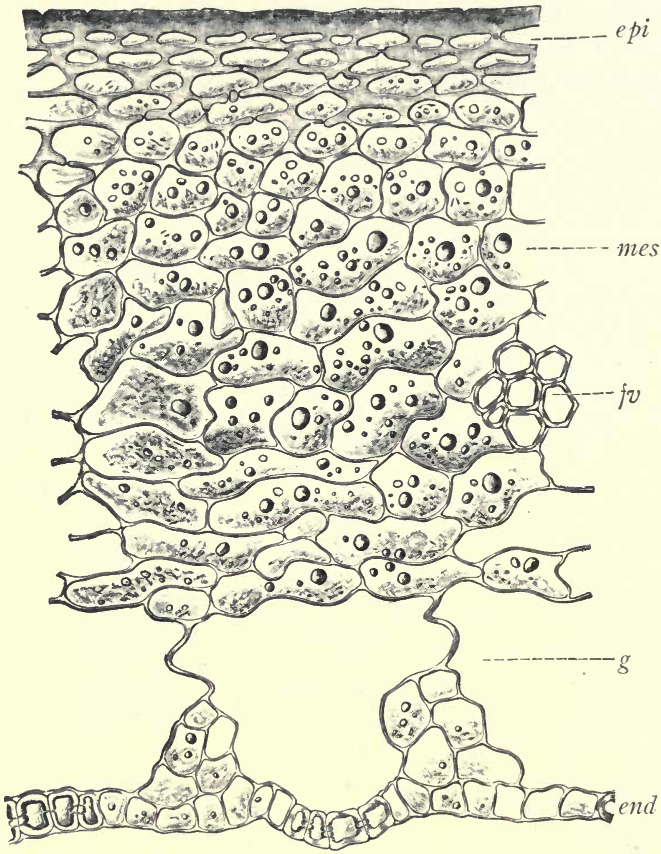

FIG. 435. Paprika. Pericarp in cross section. *epi* epicarp; *mes* mesocarp with oil globules, and *fv* fibro-vascular bundle; *g* giant cells; *end* endocarp. (MOELLER.)

beaded, 45–95 μ in diameter. They are not, as in Cayenne pepper, rectangular and arranged in rows.

2. *Hypoderm.* Several layers of collenchyma further distinguish paprika from Cayenne pepper. As was first shown by Molisch, the walls of these layers, as well as of the epicarp, are suberized, and become yellow with alkali. Contained in both the hypoderm and mesocarp in the fresh condition are oil drops and red chromoplastids which give the fruit its

characteristic color. Viewed in water, the oil drops from the dried fruit are of a bright orange or red color due to the solution of the coloring

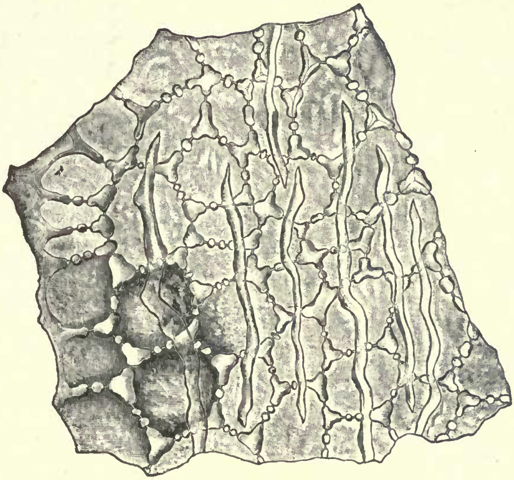

FIG. 436. Paprika. Epicarp in surface view, showing narrow grooves. (MOELLER.)

matter of the chromoplastids, and are of great aid in diagnosis. Concentrated sulphuric acid imparts an indigo-blue color to the globules, a reaction due to the action of the acid on the coloring matter. Exceedingly minute

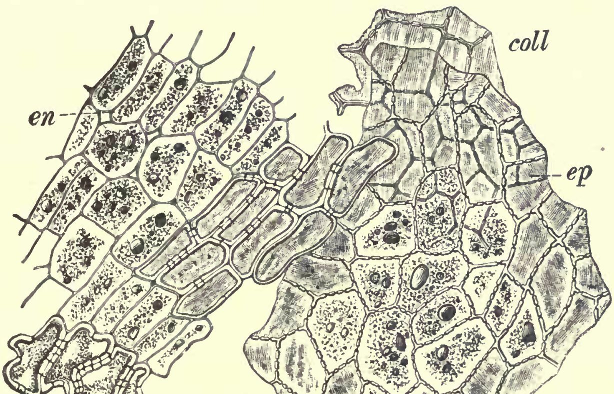

FIG. 437. Paprika. Elements of pericarp in surface view. *ep* epicarp; *coll* collenchyma; *en* endocarp with *st* sclerenchyma cells. ×160. (MOELLER.)

starch grains are occasionally found in some of the cells, particularly if the fruit is not fully ripe.

3. *Mesocarp* (Fig. 435, *mes*). The cells in the middle portion of the pericarp are thin-walled and not characteristic except for their contents. Through these cells run the bundles.

4. *Giant Cells* (Fig. 435, *g*). Adjoining the endocarp is a layer of cells of enormous size, often 1–2 mm., separated from each other by smaller cells. They are best seen in carefully prepared transverse sections. These cells are evident to the naked eye on the inner surface of the pericarp as longitudinally elongated blisters (Fig. 438).

FIG. 438. Paprika. Endocarp and giant cells in surface view. (MOELLER.)

5. *Endocarp* (Figs. 435 and 437). The most characteristic layer of the pericarp is the endocarp, made up over the giant cells of groups of sclerenchyma elements and in other parts of thin-walled cells, both kinds of cells being more or less elongated and quadrilateral with wavy outline. Penetrating the radial walls of the sclerenchyma cells are distinct pores which broaden at the middle lamella.

Pericarp, Partition Walls. Cross-sections of the partition walls show that the mesocarp consists of thin-walled elements of no especial interest, while the endocarp cells are more or less thickened. As was discovered by Arthur Meyer, the cuticle here and there separates from the cells, forming blister-like cavities in which are tabular or prismatic crystals of capsaicin, the pungent principle of the fruit. If alkali is run under the cover-glass, the crystals at first disappear, but others of octahedral form, the alkali compound, take their place. If these blisters are opened and the minutest portion of the contents transferred to the tongue by means of a needle, an intense burning sensation is experienced. In the fully ripe fruit this pungent principle is distributed throughout the pericarp and also the seeds.

The Spermoderm (Figs. 439 and 440) has an outer and inner epidermis, and between them a parenchymatous layer several cells thick, all of which are evident in sections cut from the dry seed.

1. *The Outer Epidermis* (*ep*) of highly characteristic elements, has been carefully studied by Arthur Meyer, T. F. Hanausek, and others. Seen in cross-section, the outer wall is a cellulose band of even thick-

ness (12–20 μ), covered without by a thin cuticle and within by an equally thin sclerenchymatized lining, while the radial and inner walls are enormously but irregularly thickened and sclerenchymatized. From the inner wall wart-like protuberances extend into the cell cavity. The radial walls diminish in thickness from within outward, resembling buttresses. Where they meet the outer wall, they are pierced by pores which, in cross-section, appear as slits between finger-like divisions. At the edges of the seed, where the cells often have a radial diameter upwards of 200 μ, these pores occur in the greatest numbers. In surface view the appearance differs according to the depth of the focus. On the inner wall we see warts, pores, and wrinkles; on the outer, an even structure bounded by the curiously sinuous and porous radial walls. The appearance of the latter is best described by the term "intestine cells," first applied to this layer by Moeller.

FIG. 439. Paprika. Outer portion of seed in cross section. Spermoderm consists of *ep* epidermis, *p* parenchyma, and inner layers of compressed parenchyma; *E* endosperm. ×160. (MOELLER.)

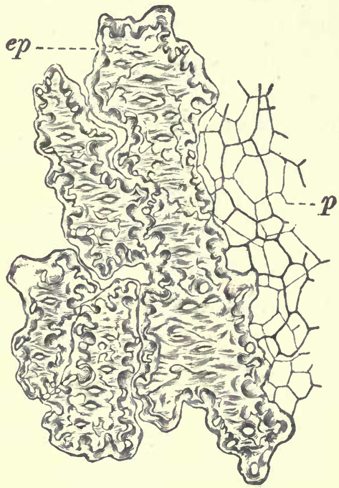

FIG. 440. Paprika. Spermoderm in surface view. *ep* epidermis; *p* parenchyma. ×160. (MOELLER.)

2. *Middle Layers* (*p*). Thin-walled cells, in the dry seed more or less compressed, form several indistinct layers.

3. *An Inner Epidermis*, also of thin-walled elements, in cross-section, is clearly seen to be in close contact with the endosperm.

The Endosperm (Fig. 439, *E*) consists of moderately thick-walled cells containing aleurone grains and fat as reserve material. A crystalloid is present in each of the aleurone grains.

Embryo. Of little interest to us are the delicate tissues of the embryo. The cell-contents are the same as in the endosperm, except that the aleurone grains are somewhat smaller.

DIAGNOSIS.

The powder is either red, yellow, or brown, according to the variety or the method of preparation, and the oil drops, seen under the microscope, are of the same color as the fruit. Treatment with concentrated sulphuric acid imparts a blue color to the oil drops.

The endocarp (Fig. 437) of elongated, sinuous cells, some sclerenchymatized (*st*), others thin-walled (*en*), and the curious intestine cells (Fig. 440, *ep*) of the outer epidermis of the spermoderm, are the tissue elements most easily found and identified. Starch is seldom present in noticeable amount, and never in the form of large grains. Tissues of the stem and calyx should not be overlooked. The epicarp cells (Fig. 436) are polygonal, have moderately thick, beaded walls, and are easily distinguished from the quadrilateral cells in rows of the corresponding layer of Cayenne pepper.

The adulterants of paprika are various products of cereals and oil seeds, nutshells, sawdust (particularly of red sandalwood (Fig. 28) and other red or brown woods), turmeric, brick-dust, etc. If the material is not of a suitable color it is often dyed with coal-tar colors, or mixed with a pigment.

The color of red sandalwood is extracted by treatment with alkali; the coal-tar dyes commonly employed are readily transferred to a bit of woollen cloth, previously heated with very dilute soda, by boiling with 1 per cent solution of potassium bisulphate—a method first devised by Arata for testing wines.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Berg (3); Greenish (14); Hanausek, T. F. (10, 16, 17, 48); Harz (18); Hassall (19); Leach (25); Macé (26); Meyer, A. (27, 28); Moeller (29, 30, 31, 32); Planchon et Collin (34); Schimper (37); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (43, 45).

HARTWICH: Ueber die Epidermis der Samenschale von Capsicum. Pharm Post. 1894, **27**, 609, 633.

HARTWICH: Ueber die Samenschale der Solanaceen. Vjschr. d. naturf. Ges. in Zürich. 1896, **41**, Jubelband II, 366.

HANAUSEK, T. F.: Ueber die Samenhautepidermis der Capsicum-Arten. Ber. d. deutsch. botan. Ges. 1888, **6**, 329.

LOHDE: Ueber die Entwicklungsgesch. und den Bau einiger Samenschalen. Dissertation, Leipzig, 1874, 26.

MEYER, ARTHUR: Der Sitz der scharfschmeckenden Substanz im spanischen Pfeffer. Pharm. Ztg. 1889, **34**, 130.

MIKLOWN: Adulteration of Spanish Pepper. Weekly Drug News. 1886, 215.
MOLISCH: Collenchymatische Korke. Ber. d. deutsch. botan. Ges. 1889, 7, 364.
MORPURGO: Delle Spezie. Trieste, 1904.
VEDRÖDI: Untersuchung des Paprikapfeffers. Ztschr. Nahr.-Unters. Hyg. 1893, 7.

CAYENNE PEPPER.

This spice, also known as red pepper and chillies, is much more pungent than paprika and is preferred to the latter in England and the United States. It is obtained from *Capsicum fastigiatum* Bl. (*C. minimum* Roxb.), *C. frutescens* and other small-fruited species grown in various parts of Africa, the East Indies, and tropical America.

Zanzibar Cayenne pepper, one of the best grades, consists of small pods 0.5 to 2 cm. long, of a dull-red color, together with slender, more or less detached stems. The seeds are but 3–4 mm. in diameter.

Bombay peppers, known also as capsicums, are an inferior grade of Cayenne pepper, said to come from the vicinity of the river Niger in Africa, not as the name would indicate, from India. The dull yellow

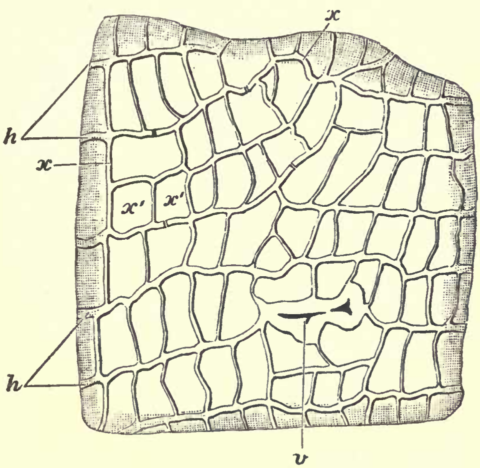

FIG. 441. Cayenne Pepper (*Capsicum frutescens*). Epicarp in surface view. *x–x*, *x'–x'* rows of cells; *h* thickened horizontal walls; *v* abnormally thickened cell. (T. F. HANAUSEK.)

or brown fruits are larger than Zanzibar peppers (2–3 cm. long and nearly 1 cm. broad), but do not differ from them in structure.

Japan Cayenne peppers are about the same size as the Zanzibar product, but are brighter in color and more glossy, although not so pungent. Their anatomical structure would indicate that they are fruits of a different species.

HISTOLOGY.

While the structure is analogous to that of paprika, certain elements are strikingly different, thus enabling the microscopist to distinguish sharply between the two species.

The Pericarp of the dry fruit is hardly thicker than a sheet of writing-paper.

1. *Epicarp* (Figs. 441 and 442). In surface view this coat is radically different from that of paprika. The cells are usually quadrilateral, more or less wavy in outline, and what is most noticeable, are arranged in distinct longitudinal rows. They are smaller than those of paprika, being but 20–55 μ in diameter, and have indistinctly beaded walls, which (double) are 3–5 μ thick.

2. *Hypoderm.* Cross-sections show that a hypodermal collenchyma of suberised cells is entirely absent, the character of the tissues chang-

FIG. 442. Cayenne Pepper (*Capsicum fastigiatum*). Epicarp in surface view. ×110. (LEACH.)

ing abruptly from the thick, sclerenchymatous epidermis to the thin-walled tissues of the mesocarp. This distinction, however marked in cross-section, is not of service in the examination of the powder.

3. *The Mesocarp*, and 4. *The Giant Cells* are quite like the corresponding layers of paprika.

5. *The Endocarp Cells* of the two species are also very similar, but are somewhat smaller in Cayenne pepper.

Spermoderm. 1. *The Epidermal Cells* are of the same general form as those of paprika, but the inner sclerenchymatized lamella of the outer wall is more strongly developed than the middle lamella, whereas in paprika the middle lamella alone is conspicuous. In surface view the cells are somewhat smaller than the epidermal cells of paprika.

2. *The Middle Layer*, and 3. *The Inner Epidermis* are not characteristic.

The Endosperm and Embryo agree in structure with the corresponding parts of paprika.

DIAGNOSIS.

In cross-sections the lack of sclerenchymatized collenchyma in the hypoderm, the thinner mesocarp, and the broader inner lamella of the outer wall of the spermoderm serve to distinguish this fruit from paprika. These distinctions are of no service in the examination of the powder, but the highly characteristic epicarp cells (Figs. 441 and 442) suffice for positive identification.

Characteristic elements common to both fruits are the oil drops of a red or orange color, the thick- and thin-walled cells of the endocarp (Fig. 437, *st*, *en*), and the outer epidermal cells (Fig. 440, *ep*) of the spermoderm (intestine cells).

The adulterants of both powders are the same and are enumerated under paprika.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Greenish (14); Hanausek, T. F. (10, 16, 17, 48); Hassal (19); Moeller (29, 30, 31, 32); Planchon et Collin (34); Vogl (43, 45).

See also Bibliography of Paprika p. 522

HANAUSEK, T. F.: Zur Charakteristik des Cayennepfeffers. Ztschr. Nahr.-Unters Hyg. 1893, 297.

ISTVANFFI: Zur Charakteristik des Cayennepfeffers. Bot. Centralbl. 1893, **3**, 468.

WALLIS: The Structure of *Capsicum minimum*. Pharm. Jour. 1901, **13**, 552.

WALLIS: The Structure of Japanese Chillies. Pharm. Jour. 1902, **69**, 3.

WALLIS: Capsici Fructus. Pharm. Jour. 1897, **59**, 467.

MYRTACEOUS FRUITS (*Myrtaceæ*).

Allspice is the only fruit of this family of importance as a spice. Cloves, the leaf bud of a myrtaceous plant, is described on p. 397.

ALLSPICE

Although most of the plants producing spices are natives of the East, the tree yielding allspice, pimenta, or Jamaica pepper, (*Pimenta officinalis* Lindl.), is an American species, growing wild in the West Indies, South America and Mexico, and extensively cultivated in Jamaica. Its fine form, abundant, shining evergreen foliage, and delightful fragrance combine to make it an attractive object in tropical gardens.

Tobasco or Mexican allspice, is a large-berried variety of *P. officinalis*, regarded by some as a separate species. Crown allspice (*Poivre de Thebet*), the fruit of *Pimenta acris* Sw., with berries 8–10 mm. long, is also gathered in tropical America. Both of these have practically the same structure as common allspice.

The fruit at full maturity is a two-celled, less often one- or three-celled, dark purple berry 5–8 mm. in diameter, crowned with a four-toothed calyx; each cell contains a plano-convex, chocolate-colored seed. The spice of commerce consists of the berries picked when fully formed, but still green, and dried in the sun. The berries are dark brown with a rough surface and have a flavor supposed to resemble a mixture of cloves with other spices, hence the English name allspice.

The seeds consist of a brown spermoderm and a snail-like, spirally-coiled embryo with a long thick radicle and minute cotyledons. They contain from 3–6 per cent of a volatile oil, and are therefore but about one-quarter as strong as cloves, the product of a tree of the same family.

HISTOLOGY.

After soaking in water, whole berries and seeds removed from the berries, separate sections are prepared of the pericarp and spermoderm.

Pericarp (Figs. 443–445). The outer wall of the pericarp, which differs somewhat in structure from the partitions between the cells, is first examined.

1. *Epicarp Cells* (Fig. 444, *ep*) of notably small size, containing a dark-brown material, and here and there well developed stomata, form

the outer layers of the pericarp. Hairs up to 200 μ long, characterized by their thick walls, and in their outer portions by their exceedingly narrow lumens, are scattered over the surface, particularly in the neighborhood of the calyx teeth.

2. *The Outer Mesocarp* with *Oil Cavities*, forming about one-quarter of the thickness of the pericarp, should first be studied in cross-section. The ground tissue consists of small thin-walled cells somewhat larger

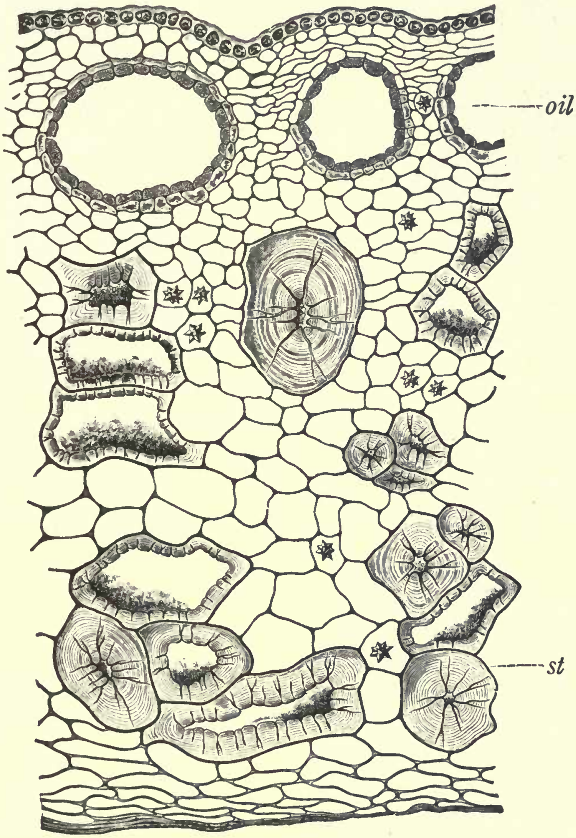

FIG. 443. Allspice (*Pimenta officinalis*). Outer wall of pericarp in cross section. *oil* oil cells; *st* stone cells of mesocarp. (MOELLER.)

than those in the epicarp, those about the oil cavities forming one or more concentric layers. The oil cavities (Fig. 443, *oil*) are rounded sacs, up to 200 μ in diameter, similar to those occurring in cloves. Over these the epicarp and mesocarp are somewhat distended, forming the wart-like irregularities seen on the surface of the fruit.

3. *The Inner Mesocarp* with numerous *Stone-Cells* (Fig. 443, *st*) makes up the major part of the pericarp. The cells of the ground tissue increase in size from without inward, and are either empty or contain formless brown masses or else crystal clusters of calcium oxalate. The stone cells are irregular in shape and have colorless walls more or less strongly thickened, in which branching pores and concentric markings are conspicuous. They are distributed through the parenchymatous ground tissue, being especially numerous in the inner layers, where they form a nearly continuous coat one or more cells thick.

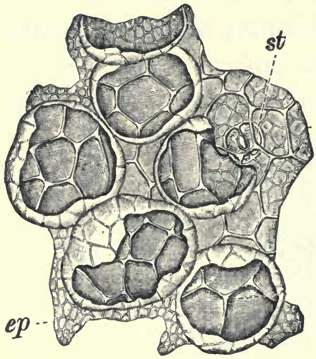

FIG. 444. Allspice. Surface view of *ep* epicarp and *st* oil cells. ×160. (MOELLER.)

4. *Compressed Cells* in several layers line the cavity of the berry. In surface view these cells, particularly those in the inner layer, are polygonal in form.

We find in the parchment-like partition walls epidermal layers of polygonal cells, a more or less obliterated ground tissue containing crystal clusters, and distributed through the ground tissue numerous fibrovascular bundles and occasional stone cells (Fig. 445).

Spermoderm (Fig. 446). Cross-sections show that this layer is thin on the edges of the seed, but on the broad sides forms thick cushions.

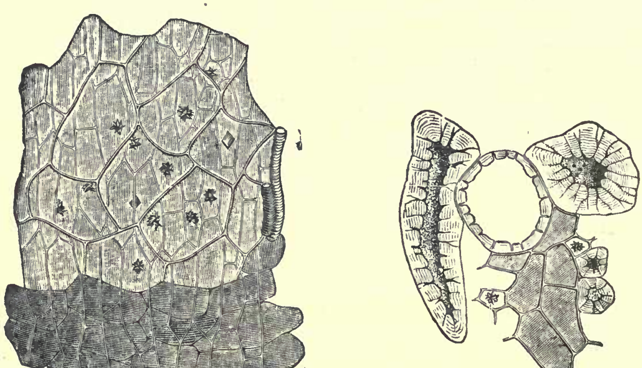
FIG. 445. Allspice. Elements of partition wall in surface view. ×160. (MOELLER.)

1. *The Outer Epidermis* (*ep*) is of narrow elongated cells.

2. *The Middle Layers* (*p*) are characterized by the pigment cells of irregular form with contents of a clear port-wine color, which are readily

found in the powdered spice. It is these cells that form the greater part of the thickened portion on the sides of the seed. Fibro-vascular bundles of the raphe and its branches ramify in the inner layers.

3. *An Inner Epidermis* of elongated cells is seen in sur ace view.

Vogl notes that the spermoderm is divided into an outer coat including the pigment cells and bundles, and an inner coat of but a few cell layers. As the inner coat is not evident in all seeds or in all parts of the same

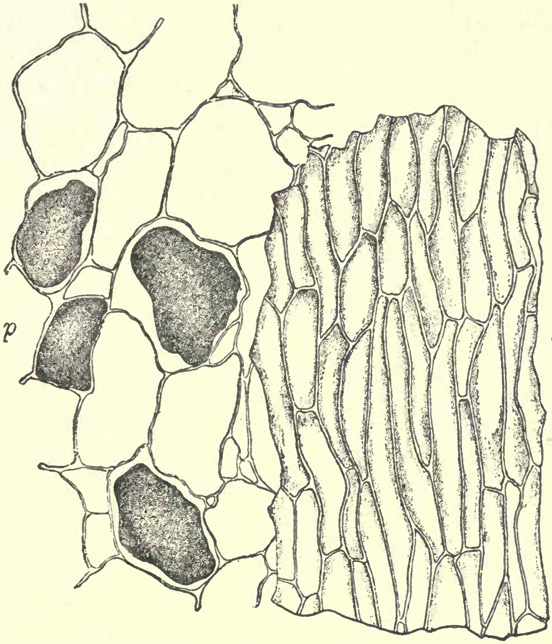

FIG. 446. Allspice. Spermoderm in surface view. *ep* epidermis; *p* brown parenchyma (port wine cells). (MOELLER.)

seed, it is possible that it does not belong to the spermoderm, but is a remnant of the endosperm or perisperm.

Embryo (Fig. 447). On soaking seeds for a day or two in 1¼ per cent caustic-soda solution, the spermoderm may be removed from the embryo. Under a lens the latter is seen to consist of a long radicle coiled in a snail-like spiral of two turns, diminishing in size from the thick lower end near the hilum of the seed to the upper end bearing the minute cotyledons. Cross-sections of the seed pass through the radicle in two or more places and may also pass through the cotyledons. By far the larger part of the seed is radicle.

1. *The Epidermal Cells* contain coloring matter but no starch.

2. *Oil Cavities* in a ground tissue of parenchyma, similar to those of the pericarp, form a ring about the radicle.

3. *Starch Cells* make up the great mass of tissues. The rounded starch grains (up to 12 μ) have a distinct hilum and are often united into twins or triplets. They resemble closely the starch of nutmeg and cinnamon.

DIAGNOSIS.

The chief elements of allspice powder are rounded starch grains (Fig. 447), occurring singly, in pairs, or triplets, each with a distinct hilum; pigment cells (Fig. 446, *p*) of the spermoderm with port-wine-colored contents (blue or green with ferric chloride); white stone cells of the mesocarp; oil cavities of both the mesocarp and embryo; small epicarp cells; and hairs with walls strongly thickened toward the apex.

Ground allspice is adulterated with various cheap materials, some of which, such as clove stems, allspice stems, ground cocoanut and other

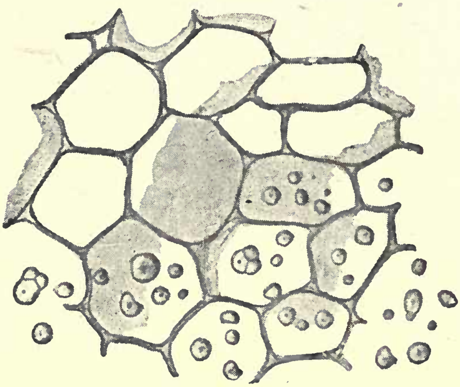

FIG. 447. Allspice. Starch parenchyma of cotyledon. (MOELLER.)

nut shells, cocoa shells, dried pears and red sandalwood, are naturally of a brownish color, and others, including cereal preparations, legumes etc., are colored brown either by roasting or by the addition of iron oxide, dyes, etc.

Cocoanut shells are distinguished by the isodiametric and slender elongated stone cells with brown walls, occurring either isolated or in dense masses; cocoa shells by the epidermis, the numerous small spiral vessels, and the sclerenchyma cells of the spermoderm; sandalwood by the characteristic wood elements, and the red color extracted by alkali. Other adulterants, such as cereal products, legumes, oil seeds, are detected by the characters noted under the several seeds.

Allspice stems are present in small amount as an accidental impurity in the genuine allspice of commerce; but when the amount is large, willful adulteration is to be suspected. A much more common adulterant of ground allspice is clove stems, which closely resemble the genuine product in composition and appearance. Spaeth, who has studied the comparative anatomy of the stems of the two plants, finds: (1) allspice stems have one-celled hairs of various forms, with a globular thickening on one side, while clove stems are not hairy; (2) the bast fibers and wood elements of allspice stems are less strongly developed and of a lighter color than those of clove stems; (3) the stone cells of allspice stems are not abundant, and for the most part are small, light-colored, and uniformly thickened, whereas those of clove stems are more numerous, mostly yellow in color, and often thickened only on one side; (4) conspicuous epidermal cells occur only in clove stems.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Hanausek, T. F. (10, 16); Hassall (19); Leach (25); Macé (26); Moeller (29, 30, 31, 32); Planchon et Collin (54); Schimper (37); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (43, 45).

HANAUSEK, T. F.: Ueber einige, gegenwärtig im Wiener Handel vorkommende Gewürzfälschungen. Ztschr. Nahr.-Unters. Hyg. 1894, 8, 95.

MORPURGO: Delle Spezie. Trieste, 1904.

NEVINNY: Die Piment-Matta. Ztschr. Nahr.-Unters. Hyg. 1887, **1**, 46.

SPAETH: Zur mikroskopischen Prüfung des Pimentes. Forschber. Lebensm. Hyg. 1895, **2**, 419.

NUTMEGS AND MACE (*Myristicaceæ*).

The terms nutmeg and mace in the legal sense include only the products of *Myristica fragrans.* The products of *M. argentea* are inferior substitutes, while Bombay mace is a worthless adulterant.

TRUE NUTMEG AND MACE.

True nutmeg is the seed freed from the spermoderm, and true mace the arillus or seed mantle, of a tree (*Myristica fragrans* Houtt.) indigenous to the Moluccas and introduced into Java, Borneo, Sumatra, and other regions of the East Indies, as well as into Trinidad, Jamaica, St. Vincent and other West Indian Islands. To-day, as in colonial times, the Banda Islands produce a large part of the world's supply of these spices, particularly the better grades, the term "Banda" as applied to either nutmeg or mace being a mark of superiority.

In general appearance the tree resembles the orange tree, having shining deep-green leaves. It is diœcious, but to facilitate fertilization it is a common practice to graft staminate branches on the pistillate trees.

The nutmeg fruit resembles a peach in shape and size. On ripening the fleshy pericarp splits into two halves, disclosing the dark-brown seed closely clasped by the deep-red branching arillus (Fig. 448).

The mace is removed whole, dried in the sun, and sometimes sprinkled

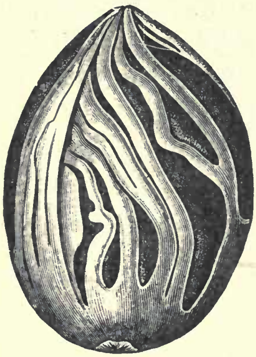

FIG. 448. Nutmeg (*Myristica fragrans*), enclosed in mace or arillus and shell or spermoderm. Natural size. (MOELLER.)

FIG. 449. Nutmeg. Seed, natural size. (MOELLER.)

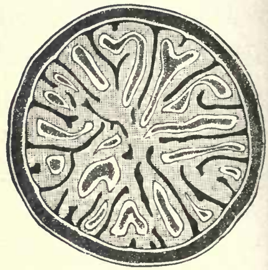

FIG. 450. Nutmeg. Cross section showing shell (spermoderm), dark veins (perisperm) and starch tissue (endosperm). Slightly enlarged. (BERG.)

with salt to insure its keeping. When ready for the market it varies from a buff to a brown color according to the variety and the care taken in curing. The seed is also dried, after which the loose nutmeg is removed from the hard, dark-brown, shining spermoderm. The latter is 1–2 mm. in thickness, furrowed on the outer surface with the imprint of the mace, and marked with a band-like raphe running from the hilum at the base to the chalaza at the apex. The nutmeg (Fig. 449) is oval, of a cinnamon-brown color, and bears numerous longitudinal wrinkles on the surface, as well as a groove corresponding to the position of the raphe. Cross-sections (Fig. 450) show a beautiful marbled appearance caused by the dark-brown branches of the perisperm penetrating into the starchy endosperm. The relatively small embryo is situated at the base.

It is the common practice to steep nutmegs in lime-water to prevent the ravages of insects as well as to improve their appearance. These limed nutmegs have a coat of carbonate of lime which may be removed in large part by friction. Penang nutmegs are usually shipped without liming.

HISTOLOGY.

Only nutmeg and mace are usually available for study, although the entire fruit preserved in alcohol, and the dried seeds, including the hard shell or spermoderm surrounded by the mace, are sometimes obtainable from spice importers.

Pericarp. 1. *The Epicarp* consists of small polygonal cells and curious multicellular star-shaped and jointed hairs, or their scars.

2. *Hypoderm.* Several layers of small stone cells underlie the epicarp.

3. *The Mesocarp* consists of rather thick-walled parenchyma, oil cells and numerous branching secretion tubes with brown contents.

4. *The Endocarp* is of soft tissues.

Arillus (Mace) (Figs. 451 and 452). The seed-mantle is a formation intermediate between a true arillus (aril) and an arillodium (arillode). Near the base, where it is cup-shaped, it divides into flattened branching

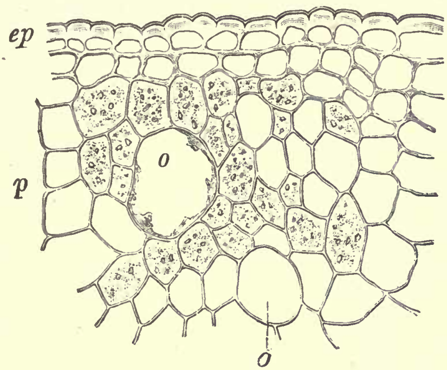

FIG. 451. Mace (*Myristica fragrans*). Cross section of outer layers. *ep* epidermis; *p* parenchyma with *o* oil cells. ×160. (MOELLER.)

arms which form an irregular network clasping the seed. As found in the market, mace is buff or brown, translucent, brittle, and agreeably aromatic, owing to the essential oil present in amounts varying from 6–15 per cent. Because of the large amount of fat (20–25 per cent), sections should be extracted with ether for the microscopic study of the other elements.

1. *Epidermis* (*ep*). The cells are longitudinally extended, sometimes reaching a length of nearly 1 mm., and vary from 20–40 μ in width.

At the ends they are either sharply pointed or truncated. From cross-sections it appears that the cuticularized outer walls are greatly thickened (6–8 μ), and that the other walls are moderately thick and swell considerably in water. Chlorzinc iodine stains the walls blue, the cuticle yellow. These cells are almost always wider than thick, thus differing

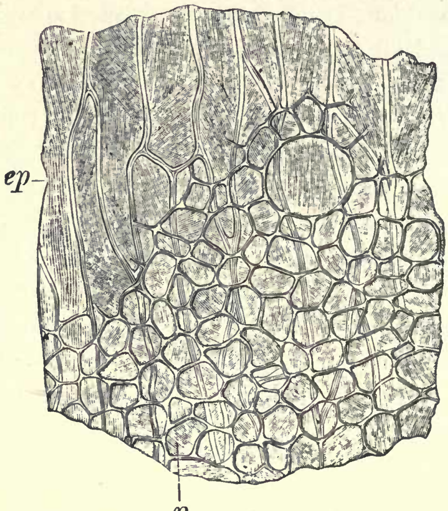

FIG. 452. Mace. Surface view of *ep* outer epidermis and *p* parenchyma. × 160. (MOELLER.)

from the corresponding cells of Bombay mace, which in cross-section are radially elongated.

2. *A Hypoderm* of collenchyma cells is found in some parts, particularly near the base.

3. *Ground Tissue* (*p*) of thin-walled, isodiametric cells 25–50 μ, large oil cells up to 80 μ, and fibro-vascular bundles, constitutes the bulk of the material. In sections previously extracted with ether, the cells of the ground tissue are seen to contain numerous curious, irregular, carbohydrate bodies with rounded excrescences, ranging in length up to 12 μ, which become red or red-brown on addition of iodine. These bodies, to which Tschirch has given the name amylodextrin starch, consist of a substance intermediate between starch and dextrine, convertible, like starch, into a soluble form by malt extract, and into dextrose by heating with acid. By the diastase method mace yields 20–30 per cent of so-called "starch," or, strictly speaking, amylodextrin starch. The oil cells contain a light yellow mixture of essential oil, resin, and fat. Addi

tion of alkali does not produce a marked coloration—never a blood-red color, as in the case of Bombay mace.

Spermoderm (Fig. 453). During drying the hard, chocolate-brown shell, consisting of the spermoderm with a portion of the outer or primary perisperm, separates from the nutmeg. Cross sections may be cut dry

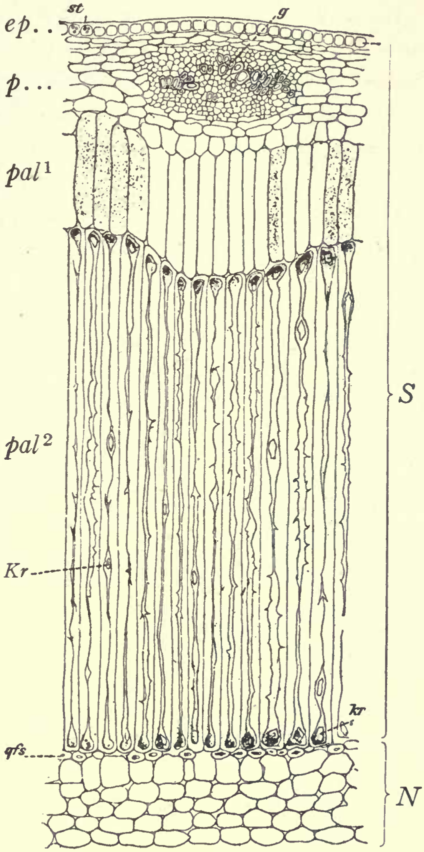

FIG. 453. Nutmeg. Shell in cross section. *S* spermoderm consists of *ep* epidermis with *st* starch grains, *p* parenchyma with *g* bundle, *pal*¹ outer palisade layer, and *pal*² inner palisade layer with *kr* crystals; *N* perisperm with *qfs* fiber layer. (HALLSTRÖM.)

and cleared with chloral, potash, or, best of all, Javelle water. Tangential sections should also be cut of both the outer and inner layers.

1. *Epidermis* (*ep*). Tangential sections show clearly the sharply polygonal epidermal cells 20–40 μ in diameter with double walls 3 μ thick; also robustly developed stomata. Brownish, amorphous cell-contents, and often starch grains are the visible contents.

2. *Parenchyma* (*p*). The cells are thin-walled and contain clear, port-wine colored masses readily separating from the cells, also occasional crystals of oxalate of lime. Fibro-vascular bundles of the raphe and its branches ramify through this layer.

3. *Outer Palisade Layer* (*pal* ¹). These cells are narrow, thin-walled, and about 150 μ high.

4. *Inner Palisade Layer* (*pal* ²). By far the larger part of the spermoderm consists of the sclerenchymatized, enormously elongated cells of this layer, which vary in height up to 1 mm. and in breadth up to 20 μ. The radial walls are remarkably straight, but the narrow lumen is irregular in outline, owing to the spiral thickening of the walls. A large crystal of calcium oxalate is often present in either end of the cell or in the central portion. As seen in cross-section, the cells of both palisade layers are wavy in outline, owing to the irregularities of the surface of the seed, formed by the pressure of the mace during growth.

Primary Perisperm (Fig. 453, *qfs*). 1. *Fiber Layer.* Tschirch and Oesterle have shown that the fibers of this layer are developed from the outer layer of the nucellus, and therefore belong with the perisperm. Seen in tangential section of the inner surface of the shell, they form an interrupted layer reminding us in their arrangement of the tube-cells of the cereals. The individual fibers are about 15 μ broad, but vary greatly in length and have irregular outlines.

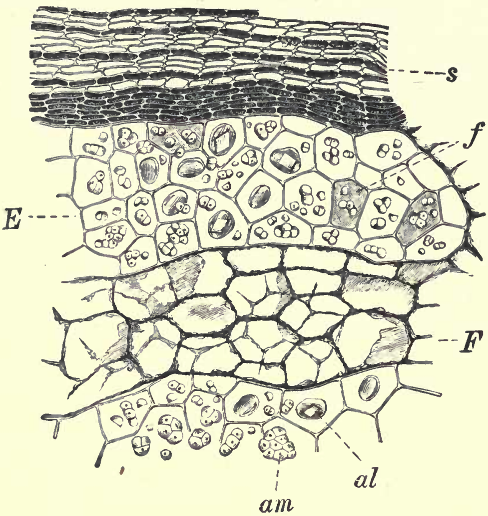

FIG. 454. Nutmeg. Cross section of kernel. *s* primary perisperm; *F* secondary perisperm of veins; *E* endosperm with *am* starch grains, *al* aleurone grains and *f* pigment cells. ×160. (MOELLER.)

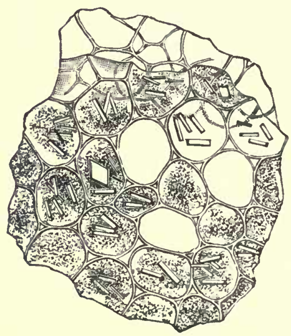

FIG. 455. Nutmeg. Tissues of perisperm from surface of kernel with brown masses and crystals. ×160. (MOELLER.)

2. *Inner Layers* (Fig. 454, *s;* Fig. 455). A portion of this tissue clings to the inner surface of the shell; the remainder forms the outer coat of the nutmeg. In tangential section the cells are rounded, 12–30 μ in diameter, with small intercellular spaces. Dark contents, also crystals, usually prismatic, less often tabular, which, according to Tschirch and Oesterle, have the reactions of bitartrate of potash, are present in the cells. The cell-walls are sclerenchymatized.

The Secondary Perispermm (Fig. 454, *F*) forms not only the inner portion of the enveloping layers of nutmegs, but also the dark fatty folds penetrating into the heart of the kernel. The cells are polygonal, for the most part smaller than in the primary perisperm, and contain more abundant brown contents. The cell-walls are of cellulose. Large secretion cells occur in the folds, in some parts in such numbers as to form nearly the whole tissue.

Endosperm (Fig. 454, *E*). The light-colored portion of the kernel constitutes the endosperm, a parenchymatous tissue consisting of starch cells and occasional pigment cells. The starch grains range up to 20 μ in diameter and occur singly, in twins, triplets, and in larger aggregates. Except for the surfaces of contact, they are rounded. Each has a distinct hilum and often radiating clefts. In addition to the starch grains, each cell contains an aleurone grain with a large crystalloid. The pigment cells contain starch grains embedded in a brown medium. These cells are lacking in the central portion of the endosperm (the "conducting tissue" of Tschirch and Oesterle) into which the arms of the cotyledons penetrate during germination.

The Embryo is located in the basal portion of the seed and has branching cotyledons for absorbing the reserve material in the endosperm.

DIAGNOSIS.

Whole Nutmegs. By far the larger part of the nutmegs of commerce reach the consumer whole, either limed, that is with a loose coat of lime adhering, or unlimed, the so-called brown or Penang nutmegs. It is customary in the trade to separate each consignment according to size, designating the different grades by the number required to weigh a pound.

It is a well-known tradition that in Colonial times, when spices were expensive luxuries, Connecticut Yankees were wont to manufacture imitation nutmegs from basswood. Whether or not this story is based on facts is uncertain, but a fraud of this kind is no more remarkable than molded nutmegs, molded coffee beans, and many other forms of sophistication practiced at the present time. The name "Nutmeg State," at first jokingly applied to the State of Connecticut, is now fixed in the language, and will doubtless persist through all time. It is needless to say that imitation nutmegs of all kinds, including the molded kernels described by Vanderplanken, Ranwez and others, can be quickly identified by the appearance and odor on cutting open the kernel.

Ground Nutmegs appear only in small amount on the market. It is no easy task to reduce a sound nutmeg to a powder because of the high percentage of oily matter; furthermore, the whole nutmeg keeps its flavor better and is readily grated as needed. Immature, worm-eaten and other inferior nutmegs are generally used for grinding; in fact, they are known in the trade as "grinding nutmegs." Certain insects devour the starchy endosperm, but avoid the resinous perisperm. We have seen kernels which had been visited by insects that lacked almost entirely the endosperm and were readily crushed between the fingers. Chemical analysis and microscopic examination showed an almost complete absence of starch, but an excess of resinous matter.

The elements of ground nutmegs especially worthy of notice are the rounded starch grains (Fig. 454, *am*) with distinct hilum, often in twins, triplets, and larger aggregates; the oil cells, pale yellow even after treatment with caustic alkali; the primary perisperm with crystals; and the brown secondary perisperm.

The adulterants include every imaginable cheap material which is, or may be made, brown in color. The materials which have been detected include nutmeg shells (spermoderm), cocoanut shells and other nutshells, cocoa shells, linseed meal, cereal matter, etc.

Whole Mace. The dried arillus, like the nutmeg, is often used whole in the household. The characters of importance in diagnosis are the longitudinally elongated epidermal cells (Fig. 452, *ep*), cross-sections of which (Fig. 451, *ep*) are tangentially elongated; the amylodextrin starch grains (seen after extraction of the fat); and the light yellow oil cells, which do not become orange with alkali. As the blades are more or less broken, it is an easy matter to adulterate with mace from inferior species.

Bombay mace (Fig. 457) has narrower blades, forming a dense tangle at the end of the arillus. If chewed, it sticks to the teeth, colors the saliva orange, and does not have a spicy flavor. Cross-sections show that the epidermal cells (Fig. 458, *ep*) are radially elongated. Treatment with alkali dissolves the dull-yellow contents of the numerous oil cells (*f*) to a blood-red liquid. The high percentage of non-volatile ether extract, as well as the deportment of the alcoholic extract toward reagents, also aids in diagnosis.

Macassar or Papua mace is identified by the broad, dark-brown blades, the peculiar wintergreen odor, and the high percentage of fat. Unfortunately it cannot be distinguished with certainty from true mace by its microscopic structure.

Ground Mace is a buff or brown greasy powder with an aroma resembling that of nutmegs, but more delicate. The noticeable microscopic characters are the amylodextrin starch grains becoming red with iodine, the elongated epidermal cells, and the oil cells. In detecting Bombay mace, the large numbers of oil-cells and the color of their contents before and after adding alkali are of chief importance, coupled, of course, with qualitative chemical tests and determinations of ether extract. Chemical analysis must be relied on to detect Macassar mace. Starchy matter, nutshells, and other foreign materials used as adulterants may usually be detected by the microscope.

Nutmeg Shells have no real value but serve as an adulterant. The powder is identified by the enormously elongated palisade cells (Fig. 453, *pal* 2), and the detached fibers of the outer layer of the perisperm.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Berg (3); Hanausek, T. F. (10, 16, 48); Macé (26); Meyer, A. (27); Moeller (29, 30, 32); Planchon et Collin (34); Schimper (37); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (43, 45).

BAILLON: Sur l'origine du maces de la muscade et des arilles en générale. Comptes rendus de l'academie, 78, 779. Adansonia, 1876, **11**, 329.

BUSSE: Ueber Gewürze. Muskatnüsse. Arb. Kaiserl. Ges.-Amte. 1895, **11**, 390, 628.

BUSSE: Notez betreffend den Nachweis von Bombay Macis in Macispulver. Ztschr. Unters. Nahr.-Genussm. 1904, **7**, 590.

HALLSTRÖM: Anatomische Studien über die Samen der Myristicaceen und ihre Arillen. Arch. Pharm. 1895, **233**, 441.

HANAUSEK, T. F.: Verfälschte Macis. Ztschr. Nahr.-Unters. Hyg. 1890, **4**, 77.

MOELLER: Ueber Muskatnüsse. Pharm. Centralh. 1880, 453.

MORPURGO: Delle Spezie. Trieste, 1904.

PFEIFFER: Die Arillargebilde der Pflanzensamen. Inaug.-Diss. Berlin, 1891.

RANVEZ: Verfälschung des Muskatpulvers durch die Muskatschalen. Ann. Pharm. 1900, **6**, 139.

TSCHIRCH: Ucuhuba, die Samen von *Myristica surinamensis*. Arch. Pharm. 1887, **66**, 619.

TSCHIRCH: Inhaltsstoffe der Zellen des Samens und des Arillus von *Myristica fragrans* Houttuyn. Tageblatt der 58 Versammlung deutscher Naturforscher u. Aertze in Strassburg, 1888.
VOIGT: Ueber den Bau und die Entwickelung des Samens und Samenmantels von *Myristica fragrans*. Inaug.-Diss. Göttingen, 1885, 365.
WAAGE: Banda- und Bombay-Macis. Pharm. Centralh. 1892, **33**, 372.

MACASSAR NUTMEG AND MACE.

Myristica argentea Warb. yields Macassar or Papua nutmeg and mace, products ranking next to true nutmeg and mace in importance.

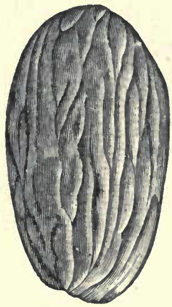

FIG. 456. Macassar Nutmeg (*Myristica argentea*). Natural size. (WARBURG.)

The nutmegs (Fig. 456), often known as long nutmegs, are 25–40 mm. long and 15–25 mm. broad, but by microscopical or chemical methods are not distinguishable from true nutmegs. The shell, as emphasized by Tschirch and Oesterle, lacks the fiber layer, a characteristic of no value in the diagnosis of the commercial product, as that is free from the shell.

Macassar Mace is darker colored than true mace and has broader blades. In its microscopic structure and chemical reactions it is much the same as true mace; in percentage composition, more like Bombay mace. It contains over 50 per cent of non-volatile ether extract, but less than 10 per cent of "starch."

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Moeller (32); Vogl (45).
Also see Bibliography of nutmeg and mace p. 539.
WAAGE: Papua-Macis. Pharm. Centralh. 1893. N. F. **14**, 131.

BOMBAY MACE.

The chief adulterant of true mace is the arillus of *Myristica Malabarica* Lam., known as Bombay mace. Although this product is obtained from a tree belonging to the same genus as true mace, it is nearly tasteless and has absolutely no value as a spice. The elongated nutmeg of this species does not come into Europe or America.

Bombay mace has much narrower and more numerous blades than the true mace. These at the apex are veriform, forming a tangled, conical mass (Fig. 457). The color is usually a deep red-brown, although sometimes it is yellow.

HISTOLOGY.

Viewed in cross-setions (Fig. 458), the radial diameter of the epidermal cells (*ep*) is greater than the tangential, whereas in true mace the reverse is the case. So far as the cell-structure is concerned, this distinction is the most important, though it is not of use except in the examination of whole mace, or at least broken mace, having fragments large enough for cutting sections. Of greater value are the reactions of the material contained in the oil cells (*f*). Examined in water, these cells are not only more numerous than in true mace, but the contents are of an orange-red color. On treatment with alkali the color dissolves to a blood-red liquid, whereas in the case of true mace the color is not greatly changed.

FIG. 457. Bombay Mace (*Myristica Malabarica*). Natural size. (WARBURG.)

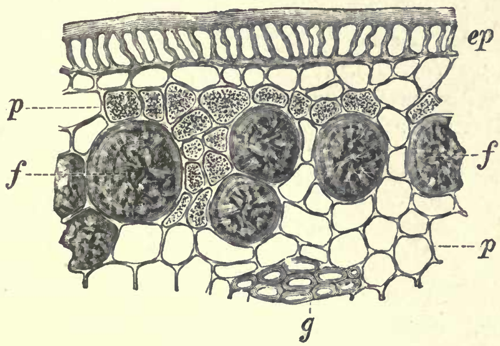

FIG. 458. Bombay Mace. Cross section of outer layers. *ep* epidermis; *p* parenchyma; *f* pigment cells; *g* bundle. (T. F. HANAUSEK.)

CHEMICAL EXAMINATION.

Chemical analysis shows that Bombay mace contains nearly 60 per cent of non-volatile ether extract, or over twice as much as true mace, but only 15 per cent of "starch."

Several qualitative methods of detection have been described, of which Busse found Waage's test and the capillary test the most reliable. The tests employing lead acetate and chrom alum are stated by the same author to be entirely unreliable, and those employing basic lead acetate (Hefelmann's test), iron alum and iron acetate were unsatisfactory. Waage's test consists in adding potassium chromate to the alcoholic extract (one part of mace to ten parts of alcohol). In the case of Bombay mace the solution becomes more or less blood-red and the precipitate, at first yellow, becomes red on standing. If only true mace is present both the solution and precipitate are yellow and do not greatly change on standing.

In making the capillary test strips of filter-paper 15 mm. broad are soaked in the alcoholic extract for 30 minutes, dried, dipped in boiling saturated baryta water, and spread on clean paper to dry. Bombay mace gives a brick-red color, but true mace and Macassar mace, a brownish yellow, faintly red in the lower part of the strip.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Moeller (30, 32); Tschirch u. Oesterle (40); Vogl (45).

Also see Bibliography of Nutmeg and Mace, p. 539.

TSCHIRCH: Bombay-Macis. Pharm. Ztg. 1881, 556.

CARDAMOMS (*Zingiberaceæ*).

The various plants yielding the cardamoms of commerce are all perennial, rush-like herbs, natives of southeastern Asia.

Two varieties of this spice are exported; the small or Malabar cardamom, and the less important long or Ceylon variety. Although the plants producing these fruits were formerly regarded as separate species, both are now classed as *Elettaria Cardamomum* White et Maton. Rarely other varieties reach the markets of Europe or America, such as Siam or round cardamom (*Amomum Cardamomum* L.), wild or bastard cardamom (*A. xanthioides* Wall), Bengal cardamom (*A. subulatum* Roxb.), and Java cardamom (*A. maximum* Roxb.).

The fruit is a three-celled capsule, often ending in a short beak, the remains of the perianth. Each cell contains two rows of closely-crowded seeds, each enveloped and cemented to its neighbor by a delicate transparent membrane, the arillus. The form of the capsule, its size and color, as well as the number and structure of the seeds, vary greatly.

MALABAR CARDAMOM.

Malabar cardamoms are rounded triangular, more or less elongated, somewhat over 1 cm. long. The leathery pericarp is light brown, yellow, or nearly colorless, longitudinally striated, and only slightly aromatic. Colorless, membranous partitions separate the fruit cavities. The seeds, usually 6–8 in number, form a coherent mass, from which, however, the individuals, each enveloped by its delicate arillus, are easily separated. They are red-brown, 2–3 mm. long, irregularly angular, transversely wrinkled, and have a sunken hilum and a raphe in a groove running nearly the length of the seed (Fig. 459). A bulky perisperm surrounds

FIG. 459. Malabar Cardamom (*Elettaria Cardamomum*). Seed with *a* arillus. ×3. (LUERSSEN.)

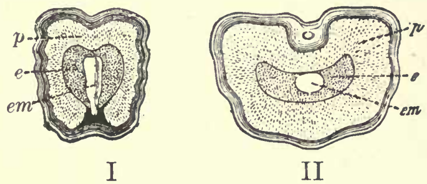

FIG. 460. Malabar Cardamom. *I* longitudinal section, ×3. *II* cross section, ×8. *p* perisperm; *e* endosperm; *em* embryo. (LUERSSEN.)

the endosperm and this in turn the minute embryo (Fig. 460). The odor is agreeably aromatic, suggesting camphor, the taste biting.

HISTOLOGY.

The Pericarp when dry is less than 1 mm. thick, but swells somewhat in water. Cross- and tangential-sections are cut either wet or dry; surface preparations of the outer and inner layers are obtained by scraping.

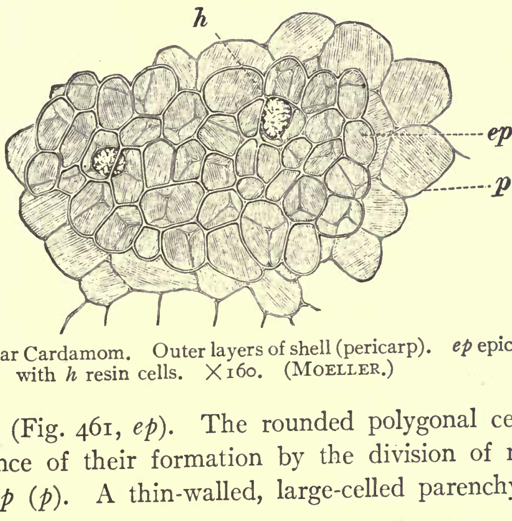

FIG. 461. Malabar Cardamom. Outer layers of shell (pericarp). *ep* epicarp, *p* parenchyma with *h* resin cells. ×160. (MOELLER.)

1. *Epicarp* (Fig. 461, *ep*). The rounded polygonal cells often show marked evidence of their formation by the division of mother cells.

2. *Mesocarp* (*p*). A thin-walled, large-celled parenchyma forms the

ground tissue, in which are numerous smaller cells containing lemon-yellow or red-brown resin lumps (50 μ). The fibro-vascular bundles have thin-walled spiral vessels (60 μ), and moderately thickened bast fibers of about the same diameter as the vessels. In the inner layers the tissue is a spongy parenchyma (Fig. 462).

3. *Endocarp* (Fig. 462). The cells are usually longitudinally extended, but some times are irregularly arranged.

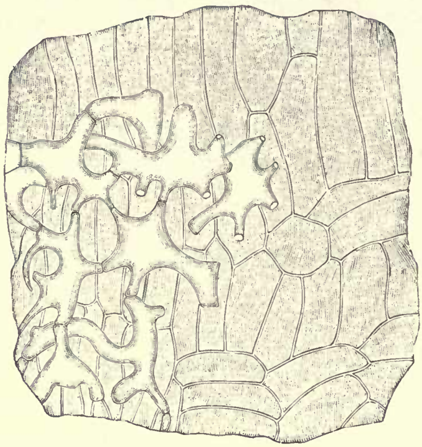

FIG. 462. Malabar Cardamom. Inner layers of shell (pericarp) showing spongy parenchyma and endocarp. ×160. (MOELLER.)

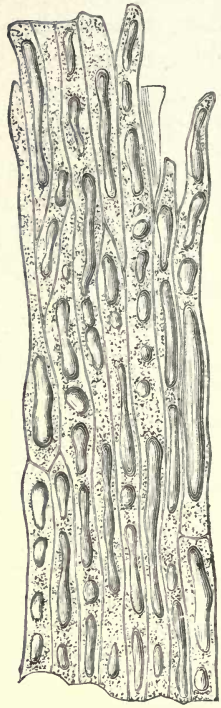

FIG. 463. Malabar Cardamom. Arillus in surface view. ×160. (MOELLER.)

Arillus (Fig. 463). The membranous, colorless seed-mantle covers the seed loosely and is attached to it at the base. At first glance it appears structureless, but on careful observation we see that it is composed of several layers of delicate, greatly elongated cells, containing strongly refractive drops and here and there crystals, either singly or in rows.

Spermoderm (Figs. 464 and 465). To cut sections it is necessary to have the hard seed firmly fixed either between corks or embedded in hard paraffine. The first and fifth layers are highly characteristic.

1. *Outer Epidermis* (*o*). This layer, like several already described, has longitudinally extended cells, but here they are very striking, because of their thicker walls, sharp outline and frequent arrangement side by side. The cells are mostly 35 μ broad and have either pointed or blunt ends.

2. *Cross Cells* (*qu*), often with brown contents giving the reactions for tannin, are indistinctly seen in cross-section, more readily in surface view.

3. *Oil Cells* (*oil*). These are large, thick cells containing the essential oil, present in the fruit to the amount of 4 per cent, and also other substances.

4. *Parenchyma* (*p*). One or two layers of cells are seen in cross-

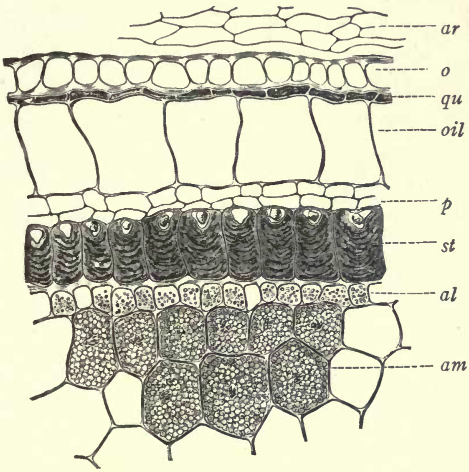

FIG. 464. Malabar Cardamom. Cross section of arillus and seed. *ar* arillus; spermoderm consists of *o* outer epidermis, *qu* cross cells, *oil* oil cells, *p* parenchyma and *st* palisade cells; perisperm consists of *al* aleurone cells and *am* starch cells. (MOELLER.)

section after swelling with reagents. In surface view they are readily found.

5. *Palisade Cells* (*st*). Because of the enormous thickening of the walls and their intense brown color, these cells form the most characteristic layer of the entire fruit. So greatly are the walls thickened that only a tiny cavity, at the outer end of each cell, remains. This cavity contains a crystal-like body. The cells are 8–20 μ broad and about 25 μ high. Focusing on the outer wall, the cells appear moderately thin-walled, much thinner than the corresponding cells of Ceylon cardamom; but focusing on the inner wall, no lumen is evident, only a compact brown mass with the sharply defined outline of the cell.

Perisperm. The outer layer contains aleurone grains, the remaining cells starch grains. The latter are minute, usually 2–3 μ and seldom over 4 μ, rounded or polygonal, and, like pepper and buckwheat starch, form dense masses conforming in shape to the cell. In the center of each mass is a hollow space containing a large crystal or several small crystals of calcium oxalate. After treatment with cold alkali, although the starch dissolves, the masses do not disappear, but form at first a granular, later a homogeneous mass, indicating the presence of a material in which the starch grains are embedded.

The Endosperm is relatively small and contains in its small, thin-walled cells aleurone grains and fat but no starch.

The Embryo has been carefully studied in various stages of growth by Tschirch, who found that it consists of an axially arranged absorptive

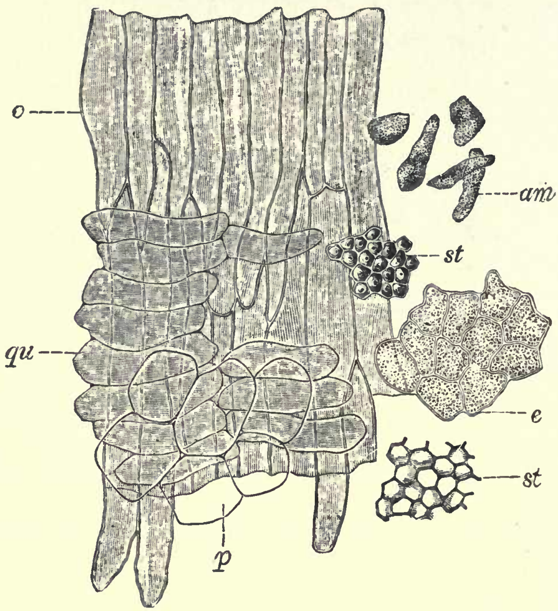

FIG. 465. Malabar Cardamom. Elements of seed in surface view. *o* outer epidermis; *qu* cross cells; *p* parenchyma; *st* palisade cells; *e* perisperm; *am* starch cells. ×160 (MOELLER.)

organ, surrounding at its basal end a minute plantlet which shows before sprouting little differentiation. The cells are small and contain the same materials as the endosperm, namely proteids and fat.

DIAGNOSIS.

Malabar or small cardamoms serve as a spice, especially as an ingredient of curry powder, and also in the making of various aromatic pharmaceutical preparations. For these only the seeds should be employed, as the shells contain little or no essential oil. It is, however, difficult to effect a complete separation, and commercial cardamom seeds invariably contain a certain amount of shell fragments. In the case of the ground seed, the presence of a large amount of shells indicates willful adulteration.

Many fragments found in the ground seed have distinctive characters. Of the perisperm elements, the masses of minute starch grains offer an excellent means of identification. The characteristic tissues of the spermoderm are the elongated epidermal cells (Fig. 465, *o*), often with adhering cross cells (*qu*), and the brown mosaic of palisade cells (*st*). The epidermal cells have the same form as the inner epidermis of the pericarp and the cells of the arillus, but have much thicker and more rigid walls. The elements of the pericarp worthy of especial notice are the yellow or brown resin masses.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674 Berg (3); Greenish (14); Hanausek, T. F. (16); Hassall (19); Meyer, A. (10, 27); Moeller (29, 30, 31, 32); Planchon et Collin (34); Schimper (37); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (45).

BUSSE: Ueber eine neue Kardamomen-Art aus Kamerun. Arb. Kais. Gesundh. 1898, **14**, 139.

HARTWICH und SWANLUND: Ueber Kardamomen von Kolombo, das Rhizom von *Zingiber Mioga* und *Galanga major*. Ber. deutsch. pharm. Ges. 1903, **13**, 141.

MORPURGO: Delle Spezie. Trieste, 1904

NIEDERSTADT: Die im Handel vorkommenden Cardamom-Arten. Chem.-Ztg. 1897, **21**, 831.

SCHADE: Entwicklungsgeschichtliche Untersuchungen über die Malabar-Cardamomen und vergleichend-anatomische Studien über die Samen einiger anderer Amomum- und Elettaria Arten. Inaug.-Diss. Bern, 1897.

SOLTSIEN: Verfälschung von Cardamomenpulver. Pharm. Ztg. 1892, 373.

TSCHIRCH: Beiträge zur Pharmakobotanik und Pharmakochemie. Schw. Woch. Chem. Pharm. 1897, No. 17.

TSCHIRCH: Ueber Cardamomen. Schw. Woch. Chem. Pharm. 1897, **35**, 481.

TSCHIRCH: Diagnose der Cardamomen. Schw. Woch. Chem. Pharm. 1897, No. 43.

WAAGE: Fructus Cardamomi. Ber. pharm. Ges. **3**, 162.

CEYLON CARDAMOM.

Long or Ceylon cardamoms are the fruit of a variety of *Elettaria Cardamomum* White et Maton, which is still classed by some as a distinct species.

The capsules are much longer than those of the Malabar variety, often reaching 4 cm., and the seeds, of which there are about 20 in each of the three cells, are twice as large, but are less aromatic.

HISTOLOGY.

Of the several distinctions from Malabar cardamoms, the presence

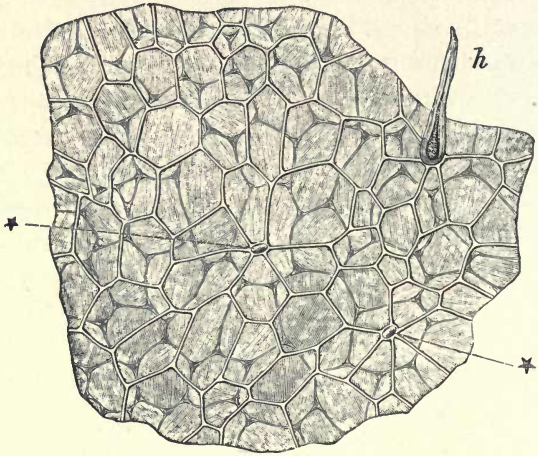

FIG. 466. Ceylon Cardamom (*Elettaria Cardamomum*). Epicarp with hairs and hair scars in surface view. ×160. (MOELLER.)

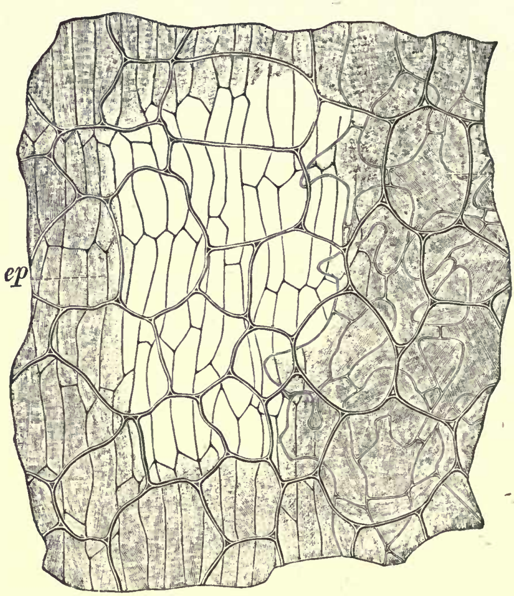

FIG. 467. Ceylon Cardamom (*Elettaria Cardamomum*). Tissues of inner pericarp in surface view, showing parenchyma, spongy parenchyma and endocarp (*ep*). ×160. (MOELLER.)

of hairs on the epicarp deserves first mention (Fig. 466). It is true that these are seldom found on the commercial product, but the scars with radiating cells about them are quite as useful in diagnosis. The outer epidermis of the spermoderm (Fig. 468, *o*) has much thicker walls (double walls 6 μ), than in the Malabar species, although the cells themselves are narrower. Other differences are too slight to be of practical use.

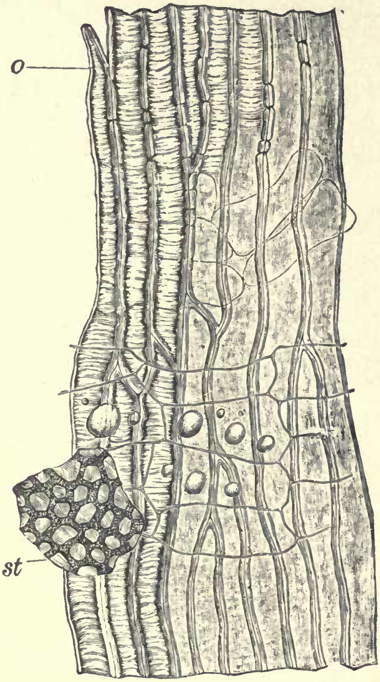

FIG. 468. Ceylon Cardamom. Tissues of spermoderm in surface view. *o* outer epidermis; *st* palisade cells. ×160. (MOELLER.)

UMBELLIFEROUS FRUITS (*Umbelliferæ*).

The inflorescence of the plants belonging to the *Umbelliferæ* is in flattened heads or umbels, a word derived from the Latin *umbella*, meaning umbrella. The flowers are small with two-celled ovaries crowned by five petals, five stamens, and usually five minute calyx teeth. The two carpels, or mericarps, are plano-convex, joined on the inner flattened side known as the commissure. On the convex or dorsal side they bear five primary ribs and sometimes four secondary ribs. When ripe the mericarps readily separate, disclosing the carpophore or prolongation of the stem to which the carpels are attached at their upper ends. In cross-section the mericarps are either semicircular or kidney-shaped. Running longitudinally through the dry pericarp, are brown, essential oil ducts or *vittæ*, which are evident to the naked eye both in cross-section and, after boiling with dilute caustic alkali, in surface view.

The epicarp is either smooth or hairy, the hairs being unicellular (anise) or multicellular (cumin).

The mesocarp has outer and inner parenchymatous layers, between which is a middle zone traversed by the fibro-vascular bundles of the ribs, and by the oil ducts, the latter being jointed and encased in a single layer of parenchyma. The ground tissue of this middle zone is largely parenchymatous, except on the dorsal side of coriander fruit, where it forms a dense sclerenchyma layer. The cells of the inner layer of the mesocarp are either isodiametric or transversely elongated, conspicuous or indistinct.

The endocarp cells are, for the most part, transversely elongated, forming a cross-cell layer, although in some species groups of cells extend in other directions, giving the layer a parqueted appearance. In breadth the cells differ greatly according to the species.

The anatropous seed consists of a thin spermoderm, usually of one distinctly cellular layer and of several obliterated layers, a bulky endosperm and a minute embryo embedded in the upper end of the endosperm. Aleurone grains 2–15 μ in diameter, containing crystal rosettes of calcium oxalate, or globoids, also fat, are the only visible contents of the endosperm. The minute radicle of the embryo is directed upward.

The fruits contain essential oils, which give them their value as flavoring materials for food products, or in medicine.

COMPARATIVE HISTOLOGY OF UMBELLIFEROUS FRUITS.

Pericarp. *Epicarp Cells* marked with delicate striations. Unicellular, warty hairs in anise; prickles (emergences) in cumin; papillæ more or less evident in celery. Epicarp smooth in all the other species.

Mesocarp. Outer layers parenchymatous in all the species and not distinctive. Middle layers of coriander on dorsal side composed of sclerenchymatized fibers with bundles but without oil ducts. In all the other species the ground tissue is parenchyma, through which pass bundles and oil ducts.

Oil Ducts. One in each groove in fennel, dill, caraway, and cumin; one to three in celery; three to six in anise.

Ribs of each fruit uniform, except in dill, where the lateral ones have wings of sclerenchyma cells perpendicular to the bundles.

Reticulated Cells accompany the bundles of fennel and dill.

The Inner Mesocarp pronounced in fennel, dill, celery, and coriander; inconspicuous in the other species. In coriander, cell-walls thickened, those of innermost layer porous; cells of inner layer in celery transversely elongated, broader than those of endocarp, more or less parqueted.

Endocarp cells narrow (mostly less than 7 μ) in fennel, dill, celery, and coriander; broader (mostly over 7 μ) in caraway, anise, and cumin. Cells parqueted in fennel, dill, and celery.

Spermoderm. Much the same in all species. Outer layer of isodiametric or transversely elongated cells. Inner layers of obliterated cells.

Endosperm. Walls thick. Cell-contents fat and aleurone grains 3–15 μ, containing oxalate crystals or globoids.

Embryo minute, of no diagnostic value.

Carpophore and Stem of woody elements.

Analytical Key to Umbelliferous Fruits.

I. Ground tissue of mesocarp parenchymatous throughout, or sclerenchymatized near the bundles only. Oil ducts on both dorsal and commissural sides.

(*a*) Endocarp cells mostly less than 7μ broad, often parqueted.

* One oil duct in each groove.

1. Ribs of uniform size.......................................Fennel.
2. Lateral ribs with wings.......................................Dill.

** One to three oil ducts in each groove.

3. Ribs and bundles small, inner mesocarp of transversely elongated cells. Celery.

(*b*) Endocarp cells mostly more than 7μ broad, seldom parqueted.

* One oil duct in each groove.

4. Epicarp smooth.......................................Caraway.
5. Epicarp with emergences.......................................Cumin.

** Several oil ducts in each groove.

6. Epicarp with warty unicellular hairs.......................................Anise.

II. Middle layers of mesocarp on dorsal side strongly sclerenchymatized. Oil ducts present only on commissural side.

7. Inner mesocarp thick-walled and porous. Endocarp cells mostly less than 7μ broad.......................................Coriander.

BIBLIOGRAPHY.

BARTSCH: Beiträge zur Entwicklung d. Umbelliferenfrüchte. Diss. Breslau, 1882.

KAYSER: Ueber das Verhältniss der Integumente der Samenanlagen zu den Samendecken der reifen Samen. Ber. pharm. Ges. 1891, **1**, 157.

KAYSER: Beiträge zur Kenntniss der Entwicklungsgeschichte der Samen mit besonderer Berücksichtigung des histogenetischen Aufbaues der Samenschalen. Pringsheims Jahrb. wissenschaft. Bot. 1893, **25**, 79.

DE LANESSAN: Observations sur le développement du fruit des Ombellifères. Bull. de la Soc. Linnéenne, 1874, No. 3.

LANGE: Ueber Die Entwicklung der Oelbehalter in den Früchten der Umbelliferen. Diss. Königsberg, 1884.

MEYER, A.: Ueber die Entstehung der Scheidewände in dem sekretführenden, plasmafreien Intercellularraume der Vittæ der Umbelliferen. Bot. Ztg. 1889, 341.

MOELLER: Das Pulver der Umbelliferenfruchte. Pharm. Post. 1892, **25**, 24.

v. MOHL: Eine Kurze Bemerkung über das Carpophorum der Umbelliferenfrucht. Bot. Ztg. 1863, 264.

TAUFANI: Nota preliminare sul frutto e sul seme delle Apiacee. Nuovo giorn. bot. ital. 1888, **20**, 307.

TAUFANI: Morfologia ed istologia del frutto e sul seme delle Apiacee. Nuovo. giorn. bot. ital. 1891, **23**, 451.

UHLITZSCH: Rückstände der Fabrikation ätherischer Oele. Landw. Vers.-Stat. 1893, **42**. 215.

VILLEPOIX: Recherches sur les canaux sécréteurs du fruit des Ombellifères. Ann. sci. natur. VI Sér. **5**, 350.

VAN WISSELINGH: Over de vittae der Umbelliferen. Gew. vergadering der afdeel. Natuurk. op. 30. Juni, 1894, 36.

FENNEL.

Fennel (*Fœniculum capillaceum* Gilb.) grows wild in various parts of Europe and Asia, and is also a common garden plant in both the Old and the New World. In Colonial times in America it was a common custom among the Puritans to carry to church a sprig of green fennel. known as "Meetin' Seed," at which they nibbled during the service.

Fruits of the cultivated varieties are from 3–10 mm. long, 1–2 mm, broad; those from the wild plant somewhat smaller. Roman or sweet fennel (*F. dulce* DC.), grown in Mediterranean countries, yields a larger fruit (Fig. 469), but with a smaller percentage of essential oil.

Fennel fruit is composed of two plano-convex carpels united on the flat commissural side, but separating easily when ripe. The commercial product consists partly of entire fruits and partly of detached carpels, the latter being bowed so that the commissure becomes concave. On the dorsal side each carpel bears five pronounced ribs. As in other

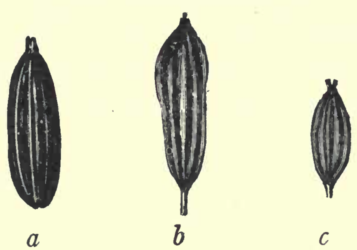

FIG. 469. Fennel (*Foeniculum capillaceum*). *a* German fennel ×3; *b* Roman fennel ×1½; *c* Macedonian fennel ×1½. (HAGER.)

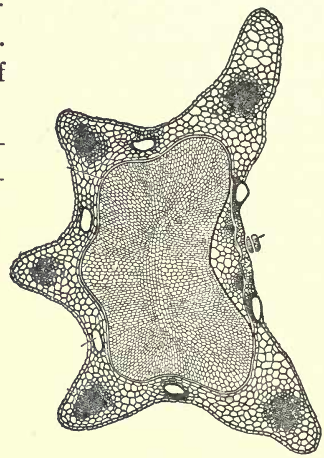

FIG. 470. Fennel. Cross section of fruit. (TSCHIRCH.)

umbelliferous fruits, the dry pericarp incloses a hard seed consisting largely of endosperm. The carpophore, or stem of the fruit prolonged between the carpels, is divided. The dry fruit contains 2–7 per cent of an essential oil, consisting largely of anethol, to which it owes its value as a drug and flavoring material.

HISTOLOGY.

Cross-sections are cut with a razor or microtome without special preparation other than soaking in water. After boiling with dilute alkali, the pericarp may be easily separated from the seed, and the spermoderm from the endosperm.

Pericarp (Fig. 470). In each of the five ribs on the dorsal side of the carpel is a fibro-vascular bundle, while in the tissues between adjoining ribs is a large resin duct. Two resin ducts run through the tissues of the commissure.

1. *The Epicarp Cells* (12–25 μ) in surface view are polygonal or quadrilateral, arranged often in longitudinal rows. Their walls are colorless and sharply defined. Small stomata occur here and there.

2. *Mesocarp* (Fig. 472). Several layers of colorless, thin-walled isodiametric cells (20–50 μ) underlie the epicarp, and two or more layers of thicker-walled isodiametric or transversely elongated cells with brown walls form the innermost layers (*b*, *c*). Between these outer and inner layers is an ill-defined zone of ground tissue, through which run the oil-ducts and fibro-vascular bundles. The oil-ducts, usually 200 μ or more broad and about half as thick, are incased by a single layer of polygonal cells of an intensely brown color (*a*). Because of this sheath, the ducts in surface view form broad brown bands in the lighter-colored ground tissue.

Quite as striking as the ducts, although lacking all color, are the bundles, of which there are six in each carpel, a large one in each of the five ribs, and a small one in the middle of the commissure, the large bundles being about the same size as the oil ducts. The bast strand is not only strongly developed on the outer side of the bundle, but extends inward to the xylem, bisecting the phloem. Adjoining each side of the bundle and extending into the ground tissue separating the bundle from the neighboring oil duct, is a group of reticulated, sclerenchyma cells, (Fig. 471), those nearest the bundle being longitudinally elongated, the others isodiametric. These reticulated cells are characteristic of fennel.

3. *The Endocarp* (Fig. 472, *d*) is made up of exceedingly narrow cross cells from 4–6 μ broad, those derived from the same mother cell being arranged side by side in groups. As a rule the cells are transversely elongated, except over the bundles where the members of different groups extend in different directions, giving the coat a parqueted appearance peculiar to this species. In cross-section the layer is about 15 μ thick.

Spermoderm. This is firmly attached to the endocarp on one side and the endosperm on the other, but can be separated by boiling with dilute alkali.

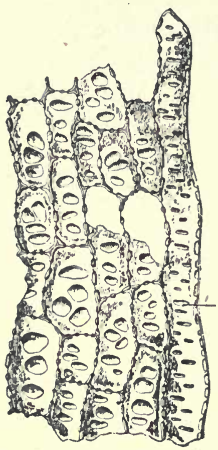

FIG. 471. Fennel. Porous parenchyma of mesocarp. (MOELLER.)

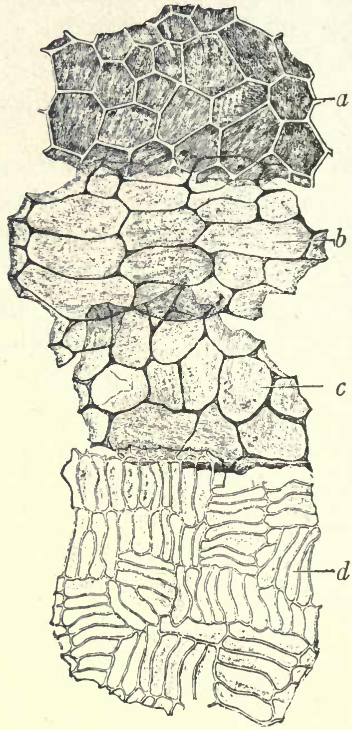

FIG. 472. Fennel. Elements of the pericarp in surface view. *a* brown cells encasing the oil ducts; *b*, *c* brown parenchyma of mesocarp; *d* endocarp. (MOELLER.)

1. *The Outer Epidermal Cells* are often transversely elongated, but are readily distinguished from the cross cells of the endocarp by their greater breadth (12–25 μ) and their arrangement side by side in long rows, not in small groups.

2. *The Inner Layers* over most of the seed form a collapsed, structureless tissue, and it is only about the raphe running through the middle of the commissure that the cells are well defined.

Endosperm. The hard, ivory-like endosperm consists of quadrilateral or polygonal, thick-walled (double walls 3–6 μ), colorless cells containing aleurone grains and fat. Examined in glycerine or turpentine, the aleurone grains are seen to be 2–8 μ in diameter, and contain one or two globoids or a calcium oxalate rosette, the latter being evident after mounting in chloral.

The Embryo is embedded in the upper part of the endosperm with its radicle directed upward.

DIAGNOSIS.

Fennel is used whole and ground, both as a drug and in cookery. The residue from the manufacture of the essential oil is fed to cattle.

Aside from the oil ducts three elements are of value in diagnosis: (1) the reticulated cells (Fig. 471) of the mesocarp; (2) the parenchyma cells of the inner mesocarp, with brown walls (Fig. 472, *b*, *c*); (3) the parqueted groups of exceedingly narrow (4–6 μ) endocarp cells (*d*). The epidermis lacks all hairs. Starch-free endosperm, with characters like those of other members of the family, forms the bulk of the fruit.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Berg (3); Böhmer (23); Collin (8); Hanausek, T. F. (16); Harz (18); Macé (26); Meyer, A. (27); Moeller (31, 32); Planchon et Collin (34); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (45).

JUCKENACK u. SENDTNER: Zur Untersuchung und Charakteristik der Fenchelsamen. Ztschr. Unters. Nahr.-Genussm. 1899, **2**, 69, 329.

MOELLER: Das Pulver der Umbelliferenfrüchte. Pharm. Post. 1892, **25**, 24.

NEUMANN-WENDER: Ueber gefärbten Fenchel. Ztschr. Nahr.-Unters. Hyg. 1897, **11**, 369.

NEUMANN-WENDER: Zur Verfälschung von Fenchelsamen. Oesterr. Chem.-Ztg. 1899, **2**, 588.

UHLITZSCH: Rückstände der Fabrikation ätherischer Oele. Landw. Vers.-Stat. 1893, **42**, 215.

UMNEY: Japan Fennel. The Chem. and Drugg. 1896, **49**, 850.

UMNEY: The Commercial Varieties of Fennel. Pharm. Jour. 1897, **58**, 225.

CARAWAY.

The so-called caraway seed, used in bread and cakes as well as in medicine, is the fruit of *Carum Carvi* L., a native of Europe, where it is also extensively cultivated. It is also grown to a limited extent in American gardens.

The fruit reminds one of fennel in appearance, but is shorter and more slender, being seldom over 5 mm. long and 1.5 mm. broad. The light-colored ribs contrast sharply with the nearly black channels between them. Cross sections of the five-ribbed carpels are nearly equilateral pentagons, the inner face, or commissure, being scarcely broader than each of the four exposed faces (Fig. 473).

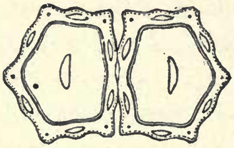

FIG. 473. Caraway (*Carum Carvi*). Cross section of fruits, enlarged. (MOELLER.)

HISTOLOGY.

The Pericarp (Fig. 474) is not so robustly developed as that of fennel.

1. *Epicarp.* The cells on the faces are polygonal, or more often quadrilateral, 15–45 μ in diameter, arranged in longitudinal rows. Over the ribs they are elongated. Stomata are present.

2. *The Mesocarp* is not so thick as in fennel and the bundles are narrower, seldom exceeding 125 μ in diameter, but on the other hand the

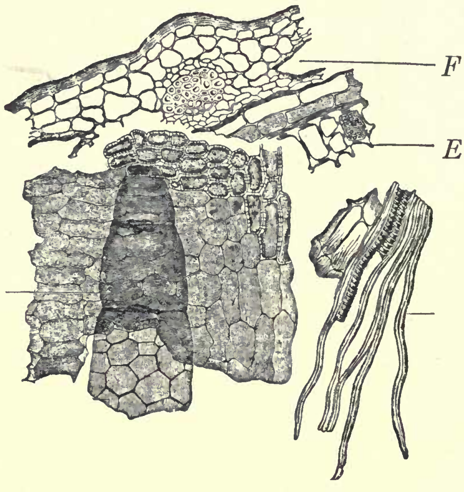

FIG. 474. Caraway. *F* pericarp and *E* endosperm in cross section; *f* fibers of bundles; *oil* oil ducts covered above with sclerenchyma. (MOELLER.)

oil ducts (*oil*) are considerably larger, the tangential diameter reaching 350 μ.

The Inner Mesocarp, as seen in cross section, is of compressed cells which are scarcely evident at all in surface view. After boiling in dilute alkali, we are able to separate out from the bundles narrow spiral vessels, somewhat broader bast fibers, and also, at the edges of the bundle near the apex of the fruit, groups of isodiametric, sclerenchyma cells. Reticulated cells such as occur near the bundles of fennel are entirely wanting. Over the broad oil ducts is an envelope of brown polygonal parenchyma cells.

3. *Endocarp.* The cells are transversely elongated, forming a cross-cell layer. Their breadth (15–25 μ) is much greater than in fennel. Although commonly placed side by side in rows, they are not parqueted.

Spermoderm. The structure is obscure owing, in cross section, to the compressed condition of the elements, and in surface view, to the hyaline nature of the walls. Preparations obtained by boiling with dilute alkali, removing the pericarp, and scraping the seed, show, with careful illumination, that the thin-walled cells of the outer layer are mostly transversely elongated. Cell-structure in the inner layers is scarcely recognizable.

The Endosperm and Embryo agree in structure with the corresponding parts of fennel.

DIAGNOSIS.

This fruit, whole or ground, is an ingredient of foods and medicines; the residue from the manufacture of caraway oil is a cattle food and adulterant.

As the structure resembles more nearly fennel than any of the other common umbelliferous fruits, it is important to note the points of difference between these two. Reticulated cells adjoining the bundles, brown polygonal parenchyma cells in the inner mesocarp, both characteristic tissues of fennel, are lacking in caraway; on the other hand, isodiametric sclerenchyma cells, such as occur near the apex of caraway, are lacking in fennel. The bundles are narrower, the oil cells larger in caraway. A most important distinction lies in the size and arrangement of the elongated endocarp cells. In caraway they are much broader than in fennel and are transversely arranged throughout—never parqueted. The epicarp (without hairs), spermoderm, endosperm, and embryo are practically the same in both fruits.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Berg (3); Collin (8); Hanausek, T. F. (16); Harz (18); Macé (23); Moeller (31, 32); Planchon et Collin (34); Villiers et Collin (42); Vogl (45).

MATTHEWS: The Vittæ of Caraway Fruits. Pharm. Jour. 1898, **60**, 259.

MOELLER: Das Pulver der Umbelliferenfrüchte. Pharm. Post. 1892, **25**, 24.

UHLITZSCH: Rückstände der Fabrikation ätherischer Oele. Landw. Vers.-Stat. 1893, **42**, 215.

ANISE.

The fruit of anise (*Pimpinella Anisum* L.), the anise "seed" of commerce, is the most delightfully aromatic of the umbelliferous fruits employed in medicine and cookery. The plant is a native of Egypt and Asia Minor, where it was cultivated in very early times. It is now grown in various parts of Europe, particularly in Spain, Italy, France, Germany, and southern Russia, also in the Orient and sparingly in America. Spain supplies the market with one of the finest grades, Russia with a grade largely used for the manufacture of the essential oil, of which the fruit contains from 1.5 to 3 per cent. Anise oil is an ingredient of various medicinal preparations (paregoric, etc.), cordials, and candies.

As found on the market the fruit is obovoid, 2–4 mm. long, 1.5–2 mm. broad, of a dull-brown color (Fig. 475). Slender stems somewhat longer than the fruit are attached to many of them. On breaking apart

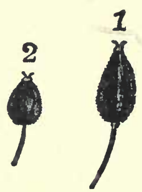

FIG. 475. Anise (*Pimpinella Anisum*). 1 Spanish or Italian; 2 German or Russian. (MOELLER.)

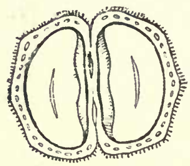

FIG. 476. Anise. Cross section, enlarged. (MOELLER.)

the carpels the inner surface is often found to be sunken in the middle. The carpophore is parted.

HISTOLOGY.

Each of the carpels in cross section (Fig. 476) reminds one of a gambrel roof, the rib on the middle of the dorsal side corresponding to the ridge-pole.

The Pericarp (Fig. 477) is characterized by the hairy epicarp and the numerous oil ducts.

1. *Epicarp.* The peculiar warty hairs (Fig. 478) which characterize this layer vary up to 200 μ in length, the longer ones being about 15 μ broad in the middle. At the apex they are blunt, at the base expanded into a polygonal cell similar in shape and size to the other epidermal cells. Some of these hairs are divided by cross partitions into two cells.

2. *Mesocarp* (Fig. 479). Running through the ground tissue on the convex side of each carpel are 20 to 45 oil ducts ranging in diameter

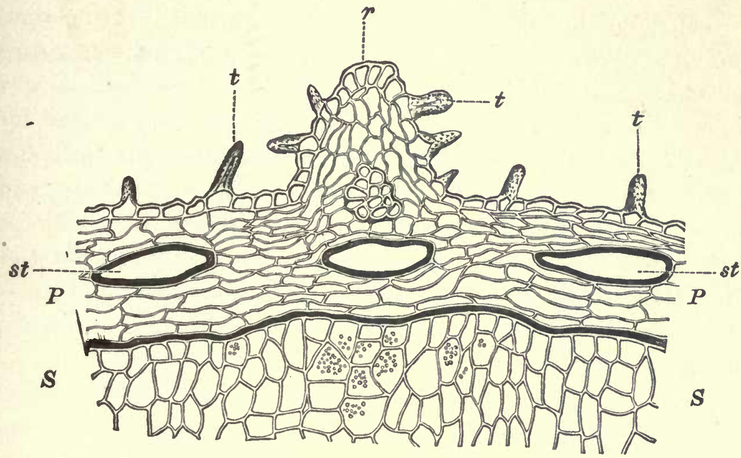

FIG. 477. Anise. Outer portion of fruit in cross section. *r* rib; *t* hairs; *P* mesocarp; *st* oil ducts; *S* endosperm. (VOGL.)

from 10–150 μ. It should be noted that the larger ducts frequently branch. Only two ducts are found in that portion of the pericarp covering the commissural face of each carpel, but these are of great breadth, reaching 300–400 μ. The bundles are small, 30–50 μ in diameter.

3. *Endocarp.* Cross cells from 7–20 μ broad form the inner layer

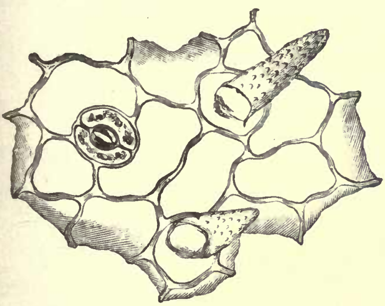

FIG. 478. Anise. Epicarp with hairs and stoma. (MOELLER.)

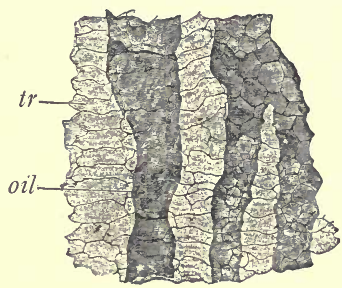

FIG. 479. Anise. Surface view of *oil* oil ducts and *tr* cross cells. (MOELLER.)

of the pericarp, except on the flattened face, where they grade into isodiametric cells often somewhat sclerenchymatized.

Spermoderm, Endosperm, and Embryo are practically the same as in fennel and caraway.

DIAGNOSIS.

Highly characteristic are the blunt, warty hairs (Fig. 478) of the epicarp. The large number of oil ducts (Fig. 479, *oil*), their branching tendency and their variable size also the cross cells of the endocarp (*tr*) further characterize the pericarp. The odor of the fruit is sweeter and more highly aromatic than that of other members of the family.

Italian anise has been found by Lochmann to contain the poisonous fruits of *Conium maculatum* L. These have a smooth epicarp, and the mesocarp contains no oil ducts. On rubbing in a mortar with potash solution a mouse-like odor is noticeable. The micro-tests for *Conium* described by Tschirch and Oesterle may also be applied. Volkart gives botanical analyses of Dutch anise containing fruits of *Conium*, *Setaria glauca*, and *S. viridis*.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Berg (3); Böhmer (23); Collin (8); Hanausek, T. F. (16); Harz (18); Macé (26); Meyer, A. (27); Moeller (31, 32); Planchon et Collin (34); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (45).

LOCHMANN: A Common and Dangerous Admixture of Conium Fruit with Italian Anise. Amer. Drugg. 1887, **16**, 81.

MODRAKOWSKI: Vergleichende Untersuchung der dem *Conium maculatum* ähnlichen Umbelliferen. Ztschr. allg. österr. Apoth.-Ver. 1903, **41**, 1215.

MOELLER: Das Pulver der Umbelliferenfrüchte. Pharm. Post. 1892, **25**, 24.

UHLITZSCH: Rückstände der Fabrikation ätherischer Oele. Landw. Vers.-Stat. 1893, **42**, 215.

VOLKART: Ueber das Vorkommen von Schierlingsfrüchten im Anis. Schw. Woch. Chem. Pharm. 1897, 614.

CUMIN.

Among the spices mentioned in the Old Testament is cumin, the fruit of *Cuminum Cyminum* L., an annual umbelliferous plant indigenous to Egypt and introduced into India, Asia Minor, and southern Europe.

The hairy carpels are 6 mm. or less in length, and have five primary and four secondary ribs (Fig. 480). In cross section they are kidney-shaped. The carpophore is divided.

HISTOLOGY.

Pericarp. 1. *The Epicarp* (Fig. 481) bears on the ribs remarkable prickles (emergences) varying up to 200 μ in length and from 25–40 μ in breadth in the middle portion, broadening at the base. Each consists of a bundle of elongated cells ending usually in a single rounded cell. These prickles are highly characteristic. The other epidermal cells have wavy walls, and in places are longitudinally elongated. Stomata occur in considerable numbers.

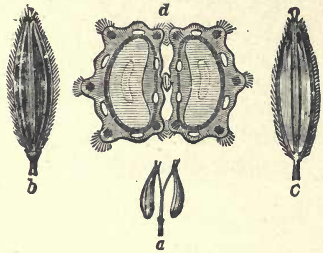

FIG. 480. Cumin (*Cuminum Cyminum*). *a* fruit, natural size; *b* dorsal side of fruit, enlarged; *c* commissural side of fruit, enlarged; *d* cross section. (HAGER.)

2. *Mesocarp.* A bundle about 50 μ in diameter is present in each of the five primary nerves, and a large oil duct, 200 μ or less broad, in each of the four secondary nerves. Still larger oil ducts, two for each carpel, are found in the commissure.

3. *Endocarp.* The cross cells of this layer are 7–18 μ broad.

Spermoderm. The cells in all but the outer layer are strongly compressed. Vogl notes that each cell contains either a single crystal or a sheaf-like bundle of crystals.

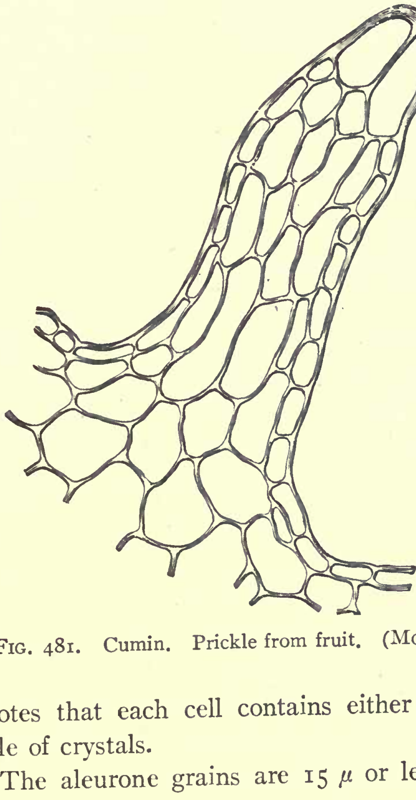

FIG. 481. Cumin. Prickle from fruit. (MOELLER.)

Endosperm. The aleurone grains are 15 μ or less in diameter, and contain oxalate rosettes or globoids. After dissolving the proteid matter in dilute alkali, the crystals are easily seen.

DIAGNOSIS.

The prickles (Fig. 481) of the epicarp furnish the chief means of identification. The cross cells are intermediate in size between those of fennel and caraway.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Berg (3); Hanausek, T. F. (16); Harz (18); Hassall (19); Macé (26); Moeller (32); Planchon et Collin (34); Villiers et Collin (42); Vogl (45).

UHLITZSCH: Rückstände der Fabrikation ätherischer Oele. Landw. Vers.-Stat. 1893 **42**, 215.

CORIANDER.

The coriander fruit (*Coriandrum sativum* L.) is a native of Italy and other countries bordering on the Mediterranean. It is cultivated in many regions for its fruit, the coriander seed of commerce, which bears little resemblance either in external appearance, histology, or flavor to the other umbelliferous fruits used as foods.

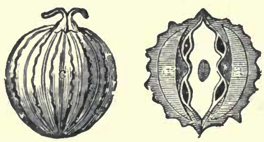

FIG. 482. Coriander (*Coriandrum sativum*). Surface view and cross section enlarged.

The fruit (Fig. 482) is globular 2–4 mm. in diameter, and is crowned with the remains of the fine calyx teeth and the small pyramidal base of the style. It consists of two closely united carpels, each with five main ribs and between them four secondary ribs, but only two oil ducts, both on the commissural side. As the carpels are strongly concave on the commissural side, the fruit is hollow and readily crushes between the teeth. The flavor of coriander is mild and agreeable. Coriandrol is the chief constituent of the essential oil.

HISTOLOGY.

Owing to the sclerenchyma layer of the mesocarp peculiar to this species, coriander is easily identified.

Pericarp (Fig. 483). For surface preparations it is recommended to boil in $1\frac{1}{4}$ per cent alkali, remove the pericarp and scrape both the outer and inner surface.

1. *Epicarp.* The sharply polygonal cells, 15–30 μ, contain crystals and crystal clusters of calcium oxalate also remains of chlorophyl grains.

2. *The Hypodermal Cells,* of which there are two or three layers, are somewhat larger than those of the epicarp, and in cross-section are tangentially elongated.

3. *Parenchyma.* Between the ribs this layer consists of large, isodiametric, thin-walled cells, and in the ribs, of longitudinally elongated,

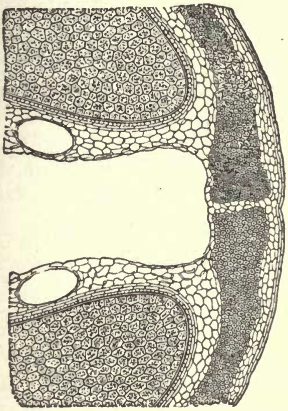

FIG 483. Coriander. Cross section through portion of the two fruits showing where they are grown together. (BERG.)

FIG. 484. Coriander. Sclerenchyma and parenchyma of mesocarp in surface view. (MOELLER.)

moderately thick-walled cells. Between this and the next layer are the insignificant fibro-vascular bundles.

4. *Fiber Layer* (Fig. 484). Tangentially extended fibers, crossing one another in different directions, form a continuous coat on the dorsal side of each carpel, but are entirely lacking on the commissure; on the other hand, two oil ducts 300–400 μ in diameter occur on the commissural side, but none are present on the dorsal side. The fiber coat is from 5–10 fibers thick (50–175 μ), being thickest in the ribs. The fibers have strongly thickened, sclerenchymatized, porous walls. A similar fiber layer occurs in the endocarp of the apple and coffee bean.

5. *Inner Mesocarp.* Isodiametric or somewhat elongated rounded parenchyma cells 25–60 μ in diameter make up two or more layers. They have yellow walls 4–8 μ thick, which, in the innermost layer, are distinctly porous.

6. *Endocarp.* Narrow cross cells 3–10 μ broad, often parqueted, remind one of the endocarp of fennel.

Spermoderm. After removal of the pericarp as above described, the spermoderm may be separated from the seed by scraping. The cells in the outer layer are polygonal, 15–25 μ in diameter, and contain a brown-green substance.

Endosperm. This, in cross-section, is narrow kidney-shaped. It contains aleurone grains like those found in other members of the family.

The Embryo presents no distinctive features.

DIAGNOSIS.

Whole coriander fruits are much used in confectionery, and also to some extent in mixtures of whole spices; the ground fruits enter into the composition of various spice mixtures and drugs.

From all other fruits of the family they are distinguished by the dense fiber layer (Fig. 484) and the presence of oil ducts only on the commissural side. The endocarp is much like that of fennel, dill, and celery, but seen in combination with the thick and porous-walled inner mesocarp cells is useful in identification.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Berg (3); Hanausek, T. F. (16); Harz (18); Macé (26); Meyer, A. (27); Moeller (32); Planchon et Collin (34); Villiers et Collin (42); Vogl (45).

PERROT: Sur l'anatomie du fruit de coriandre. Bul. Sci. Pharm. 1901, **3**, 385

UHLITZSCH: Rückstände der Fabrikation ätherischer Oele. Landw. Vers.-Stat. 1893, **42**, 215.

DILL.

Like most of the umbelliferous plants yielding fruits used for culinary purposes, dill (*Anethum graveolens* L.) is a native of parts of Europe, Asia, and Africa bordering on the Mediterranean.

The carpels (Fig. 485) are plano-convex, 3–5 mm. long, and 2–3 mm. broad. Of the five ribs, the two on the edges form wings about 0.5 mm. broad, while the remaining three on the convex surface are not pronounced. The carpophore is divided nearly to the base.

HISTOLOGY.

This fruit is distinguished from fennel by the wings on the edges. While the bundles in the other ribs are not usually over 100 μ in diameter, those in the wings reach 300 μ. The thin, chaffy edges of the wings, about 300 μ broad, consist of porous, sclerenchyma cells, in the outer layers isodiametric, in the inner layers greatly elongated (often 150 μ) and arranged perpendicular to the bundle.

On the side of the bundle nearest the seed are reticulated elements, which are either isodiametric or axially elongated.

Epicarp, Endocarp, Spermoderm, and Embryo are similar in structure to the corresponding parts of fennel.

FIG. 485. Dill (*Anethum graveolens*). ×5.

DIAGNOSIS.

Dill fruits are employed both in foods and medicines. They are distinguished from fennel by the broad wings, each with a large bundle (300 μ), and adjoining the bundle, porous, sclerenchyma elements. On the outer side these sclerenchyma cells are elongated perpendicularly to the bundle, and are distinctly but finely porous, whereas on the inner side of the bundle they are longitudinally elongated and reticulated.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674 Hanausek, T. F. (16); Harz (18).

UHLITZSCH: Rückstände der Fabrikation ätherischer Oele. Landw. Vers.-Stat. 1893, **42**, 215.

UMNEY: Some Commercial Varieties of Dill Fruits. Pharm. Jour. 1898, **61**, 176.

CELERY SEED.

Celery (*Apium graveolens* L.) is grown throughout the temperate regions of Europe and America for its succulent leaf-stalks or fleshy roots, and in France for its spicy fruits.

These are minute, 0.8–1.5 mm. long, and are shaped much like anise seed. The carpophore is entire nearly to the apex. Cross-sections of the carpels are nearly regular pentagons.

HISTOLOGY.

Pericarp. After boiling or soaking for some hours in $1\frac{1}{4}$ per cent alkali the pericarp separates from the seed.

1. *The Epicarp Cells* in surface view are sinuous in outline, the outer walls being delicately striated, and in parts extended beyond the surface in the form of warts.

2. *Mesocarp.* One, two, or three oil ducts occur in each groove on the dorsal side, while two are present on the commissural side. They

are surrounded by a layer of polygonal cells. The bundles are small, and at the apex of the seed are accompanied by groups of sclerenchyma cells.

The inner layers of the mesocarp consist of elongated cells broader than those of the endocarp (10–16 μ), but otherwise very much like them. They are for the most part transversely arranged, but groups of cells extended in other directions are not uncommon.

3. *Endocarp.* Narrow cross cells (4–10 μ), such as are found in fennel and dill, make up this layer. Although mostly transversely extended, a parqueted arrangement is not uncommon.

Spermoderm, Endosperm, and Embryo conform in structure to the usual type of umbelliferous seed.

DIAGNOSIS.

Celery seed has a limited use for seasoning soups, gravies, etc., and celery salt, a mixture of the ground seeds with common salt, is a table condiment. Before examination the latter should be freed from the salt by stirring with water, allowing the insoluble matter to settle.

Mustard seed and other cheaper spices are common admixtures.

Although none of the elements are characteristic, the presence of two cross-cell layers, one of cells 10–16 μ broad belonging to the inner mesocarp, the other of narrow endocarp cells such as are found in fennel, is of service in diagnosis. The epicarp is delicately striated and sometimes warty, but is difficult to find.

MISCELLANEOUS FRUITS AND SEEDS.

Mustards are described with the oil seeds (pp. 176–185), tonka bean with the legumes (p. 273). The following are unclassified:

STAR-ANISE.

Aside from its anise-like aroma, star-anise bears no resemblance to umbelliferous fruits. It is the fruit of a tree (*Illicium verum* Hook. fil., order *Magnoliaceæ*), indigenous to southern China and cultivated in Japan, the Philippines and other parts of the Orient. After blooming the 6–8 (rarely 9–12) independent upright carpels assume horizontal positions, forming a flat expanded rosette (Fig. 486, *1*) radiating from a central column and borne on a slender stem. The ripe carpels, 12–20 mm. long and 6–10 mm. high, are laterally somewhat flattened, pointed on the free end, and dehiscent on the upper (before expansion, the inner) side, thus making them boat-shaped. The outer surface of the pericarp is dark brown and roughened; the surface of dehiscence and the lining of the cavity are smooth and lustrous. Still more lustrous are the light-brown, obovoid, anatropous seeds, 5–8 mm. long, each containing a bulky endosperm and a minute embryo. Star-anise owes its agreeable

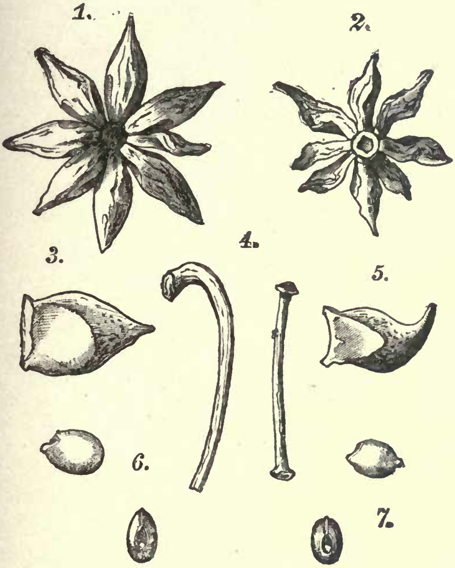

FIG. 486. Star-Anise (*Illicium verum*). 1 aggregate fruit; 3 single fruit; 4 (left) stem; 6 seed. Shikimi (*Illicium religiosum*). 2 aggregate fruit; 5 single fruit; 4 (right) stem; 7 seed. (VOGL.)

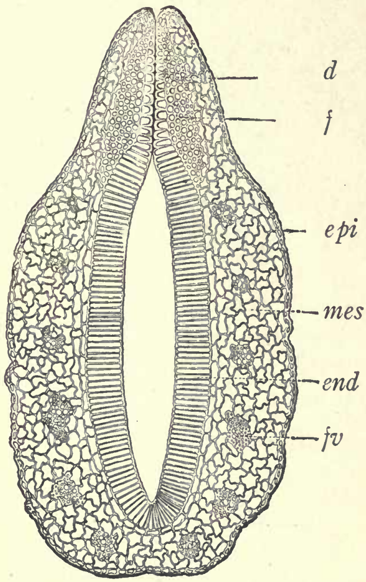

FIG. 487. Star-Anise. Cross section of fruit. *d* dehiscence slit; *f* fiber group; *epi* epicarp; *mes* mesocarp; *end* endocarp; *fv* fibro-vascular bundle. (VOGL.)

aroma to an essential oil situated in the pericarp, which, like anise oil, consists largely of anethol.

HISTOLOGY.

The microscopic structure is somewhat complicated, and includes a number of beautiful and highly characteristic elements.

Pericarp (Fig. 487). The hard pericarp should be soaked in water before making preparations. Cross sections should be cut of the whole pericarp, also longitudinal sections through the dehiscence surface. Preparations obtained by scraping the outer and inner portions of the pericarp, and tangential sections from the surfaces of dehiscence are also instructive.

1. *Epicarp* (*epi*). The roughened outer surface of the pericarp is covered with an epicarp of large cells (40–100 μ) with wavy side walls pierced by numerous pores, and greatly thickened outer walls (10–15 μ) covered with a striated cuticle. Interspersed among these cells are large stomata. Highly characteristic are the narrow, more or less paral-

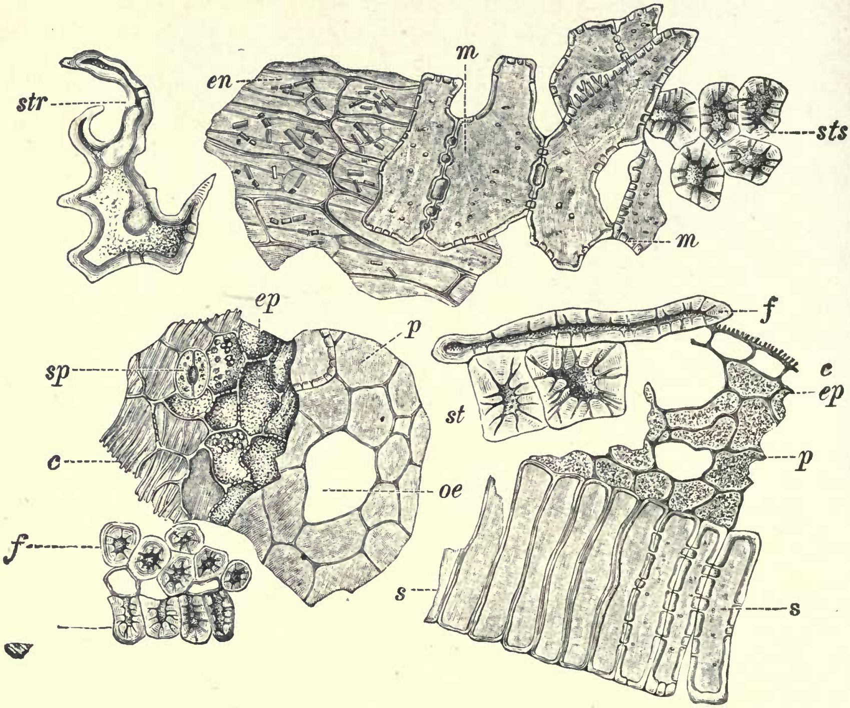

FIG. 488. Star-Anise. Elements of powder in cross section and surface view. *ep* epicarp with *c* cuticle and *sp* stoma; *p* parenchyma of mesocarp with *oe* oil cell; *str* branched stone cell; *sts* stone cells; *st* stone cells from beneath dehiscence surface; *s* palisade cells of endocarp; *m* parenchmya of spermoderm; *en* spermoderm. ×120. (MOELLER).

lel, branching and anastomosing striations of the cuticle (Fig. 488, *c*), which in cross-section appear like teeth. The contents of these cells is a red-brown material, either in homogeneous masses or globules, changing to a green color on addition of ferric chloride.

2. *Mesocarp* (*mes*). This is thickest in the dorsal (under) side of the pericarp, diminishing gradually toward the cleft of dehiscence. The cells are variable in size, and have thin, brown, wavy walls and brown

contents. Here and there are found large, rounded cells, containing essential oil, which in the ripe fruit are more or less shrunken, but assume their original form on treating tangential sections with dilute alkali. The walls of the oil cells are cuticularized and, as noted by Vogl, become intensely red on the addition of alcoholic fuchsin. Scattered through the mesocarp and more abundantly through the tissues of the fruit stem, are branching stone cells of various fantastic shapes, denominated by Tschirch "astrosclereïds." These are best obtained by maceration. Through the middle layers of the mesocarp run the bundles, of which the narrow spiral vessels, the broad reticulated vessels, and the bast fibers of various breadth, are the noticeable elements. The cells in the inner layers are smaller than in the outer and, as may be seen in cross-section, are collenchymatously thickened.

Adjoining the endocarp on each of the dehiscence surfaces (*d*) is a dense layer, 500 μ or more thick, of longitudinally arranged sclerenchyma fibers. These fibers vary greatly as to the thickness of the walls, and the breadth of the cavity.

3. *Endocarp* (*end*). A layer of sclerenchymatized but thin-walled palisade cells, reaching 600 μ in height and 60 μ in breadth, lines the seed cavity. Their shape in cross-section is sharply rectangular. In surface view they are polygonal, but the isolated cells or groups of cells obtained from the powder fall on their side, presenting the same appearance as in cross-section. Their great length and prismatic form is very noticeable. These cells pass by degrees into short, strongly thickened, porous stone cells on the dehiscence surfaces. Toward the edge of these surfaces they have thinner walls, elegantly marked with parallel reticulations.

Spermoderm (Fig. 489). Quite as striking as the elements of the pericarp are those of the spermoderm.

1. *The Outer Epidermis* (*ep*) may be separated as yellow, brittle, glassy fragments from the inner layers which are firmly attached to the endosperm. As appears in cross-section, the layer is composed of sclerenchyma palisade cells 150–200 μ high and 30–70 μ broad, the radial walls of which are very strongly thickened in the outer portion, but narrow near the inner wall, forming an inverted funnel-shaped lumen. Round and very distinct pores pierce both the radial and tangential walls.

2. *Sclerenchymatized Spongy Parenchyma* (*sub*) forms the brown subepidermal layer. The cells are large, often longitudinally elongated,

flat, and exceedingly irregular in shape (Fig. 488 *m*). Their porous membrane is impregnated with brown coloring matter.

3. *Middle Layers* (*p*). Proceeding inward, the intercellular spaces become less numerous and the walls, although still somewhat thickened,

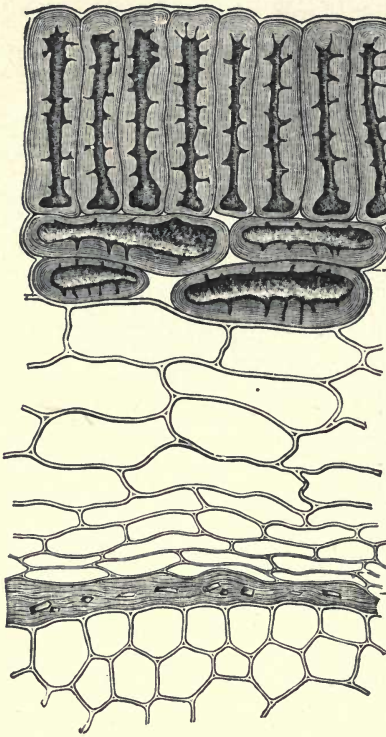

FIG. 489. Star-Anise. Cross section of outer portion of seed. Spermoderm consists of *ep* outer epidermis, *sub* supepidermal layer and *p* parenchyma; *en* inner obliterated tissue (perisperm?); *E* endosperm. (MOELLER.)

lose their sclerenchymatous character and their brown color. Elongated elements form the inner layers.

4. *Hyaline Layer* (*en*). By scraping are disclosed still other cells forming the colorless inner membrane. They appear as an indistinct layer in cross-section and are easily overlooked. Their contents are numerous, large, prismatic crystals of calcium oxalate. Some of these cells may belong to the perisperm.

Endosperm. Thin-walled cells containing fat and protein make up the endosperm. At first glance the contents appear as an amorphous, colorless mass, but after extracting the fat and treatment with alcoholic iodine a clear differentiation of the aleurone grains is obtained. These have roughened surfaces and occur to some extent singly, reaching in extreme cases 25 μ; but more often are combined to form compact masses. The individual grains contain globoids, less often single crystalloids.

The Embryo is too minute to form any considerable portion of the product, and possesses no elements worthy of notice.

The Fruit Column and Fruit Stem contain, among other woody elements, numerous astrosclereids.

DIAGNOSIS.

The fruit is seldom found in the kitchen, but is largely employed in the manufacture of medicinal preparations, cordials, and perfumes, as well as essential oil.

The histological elements resemble closely those of the poisonous fruit of shikimi (*Illicium religiosum* Siebold), but exhibit some differences noted in the subsequent chapter. Distinction from other materials is simple, owing to the highly characteristic elements of the pericarp, the spermoderm, and the fruit stem. Of especial diagnostic importance are the striated cells of the epicarp (Fig. 488, *ep*), the long, non-porous, rather thin-walled prismatic cells of the endocarp (*s*), the thick-walled, porous elements from beneath the dehiscence surface, the epidermal stone cells of the spermoderm with funnel-shaped cavities, the sclerenchymatized subepidermal spongy parenchyma (*m*), and the inner crystal-bearing layers, and finally the astrosclereids (*str*) of the mesocarp and stem. It is hardly necessary to undertake the somewhat difficult task of examining the aleurone grains except in cases where the presence of shikimi is suspected.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Berg (3); Flückiger (11); Hanausek, T. F. (16, 48); Macé (26); Meyer, A. (27); Moeller (29, 30, 31, 32); Planchon et Collin (34); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (45).

BLONDEL: L'industrie de la Badiane au Tonkin. Jour. pharm. chim. 1889, **20**, 567.

GODFRIN: Étude histologique sur les tégument séminaux des Angiospermes. Soc. d. Sci. d. Nancy, 1880, 109.

HARTWICH: Giftiger Sternanis. Schw. Woch. f. Chem. u. Pharm. 1900, **39**, 104.

LAURÉN: Giftiger und echter Sternanis. Apoth.-Ztg. 1896, **11**, 650.

LENZ: Zur anatomischen Unterscheidung der Früchte von *Illicium religiosum* Siebold und *I. verum* Hook. fil. Archiv. d. Pharm. 1899, **237**, 241.

LENZ: Ueber die Erkennung der giftigen Sikkimifrüchte im Sternanis. Pharm. Ztg. 1899, **44**, 44.

PFISTER: Zur Kenntniss des echten und des giftigen Sternanis. Vjschr. d. Naturf. Ges. in Zürich, 1892, 37, 313.
PFISTER: Zur Unterscheidung von echtem und giftigem Sternanis. Schw. Woch. f. Chem. u. Pharm. 1899.
PFISTER: Japanischer Sternanis. Ztschr. Nahr.-Unters. Hyg. 1897, 351.

SHIKIMI.

Shikimi (also spelled sikimi, sikkimi, sikimmi, skimmi) (*Illicium religiosum* Siebold) grows in Japan, especially about the Buddhist temples, hence the specific name *religiosum*.

The poisonous fruit resembles star-anise in morphological and histological structure, but in chemical composition is characterized by the absence of anethol and the presence of a poisonous principle, "shikimin." The carpels (Fig. 486) are somewhat smaller than those of star-anise, less compressed, and have a thinner beak, usually curved upward; but these distinctions are not sufficiently marked to render identification, especially in mixtures, absolutely certain. Their odor is not like that of anise.

The following are the chief distinctions from star-anise:

Star-anise. Endocarp cells highest (up to 600 μ) near the dehiscence surface, gradually passing into the cells of that surface; astrosclereids in the fruit column; aleurone grains roughened on the surface, containing globoids, rarely single crystalloids.

Shikimi. Endocarp cells highest (up to 400 μ) on under side of the fruit cavity (the side furthest from the dehiscence surface), abruptly passing into cells of dehiscence surface; rounded stone cells in the fruit column; aleurone grains distinct, smooth, and lustrous, containing 1 to 3 distinct crystalloids and many globoids.

Tschirch and Oesterle describe the following test: Grind a single carpel from which the seed has been previously removed, and boil a few minutes with 1–2 cc. of alcohol. Decant off the liquid and add water. If the material is shikimi, the liquid remains clear; if star-anise, it becomes cloudy, owing to the presence of anethol. If the alcoholic extract from shikimi is allowed to evaporate on a watch-glass, a large number of beautiful crystals of shikiminic acid appear, but the extract from star-anise yields only a few indistinct crystals.

Lenz shakes the diluted alcoholic liquid with freshly rectified petroleum ether boiling below 60°, and evaporates the ethereal solution. From star-anise a yellow oil with an anise odor is obtained, from shikimi a scarcely visible residue with a bedbug odor.

Vogl and some other authors find the shikiminic acid test unreliable.

BIBLIOGRAPHY.

See Star-anise, p. 571.

VANILLA.

An epiphytic orchid (*Vanilla planifolia* Andrew, order *Orchidaceæ*), yields the so-called vanilla beans of commerce. The term "bean" as applied to this fruit is a misnomer, as the plant is not a legume, and both the fruit and seeds are radically unlike those of legumes. The plant is a native of Mexico, whence the finest grade of vanilla is still obtained, but it is cultivated in South America, Réunion (Bourbon vanilla), the East African Islands, Tahiti, Java, Ceylon, and various tropical regions.

Mexican vanilla is almost entirely consumed in the United States, the European market being largely supplied from Réunion and Mauritius. Tahiti vanilla has a rank flavor which quite unfits it for use as a condiment.

The ripe fruits are from 12–20 mm. long, in cross-section rounded triangular, about the size of a small lead pencil. They are one-celled capsules formed by the union of three fruit leaves, but dehiscing into two longitudinal valves of unequal size. The fruits ripen in from seven to nine months; they are picked, however, when fully formed but only partially matured. The drying is effected either by sunshine, artificial heat, or calcium chloride, and is supplemented by a sweating process, which develops the delightful aroma so characteristic of the commercial product. When ready for the market the fruits are tough, flexible, dark brown, nearly black, with an oily luster, and are often coated with a bloom of fine crystals. They are marked by numerous longitudinal furrows and taper toward both ends, bearing at the apex a small head with a shallow depression. After soaking in water they swell to their original triangular shape. In cross-section (Fig. 490) the fruit is one-celled, containing great numbers of minute black seeds borne on six forked placentæ and embedded in a clear yellow balsam.

The chief flavoring principle of vanilla is not an essential oil but a crystalline solid, vanillin, present in amounts ranging from 1.5 to 3.0 per cent. In *V. pompona* Schiede, *V. Guyanensis* Split., *V. palmarum*

Lindl., and *V. aromatica* Sw., the content of vanillin is much smaller, while in *V. inodora* it is entirely absent. Vanillin occurs in considerable amount in the sap of coniferous and other woods, from which formerly it was

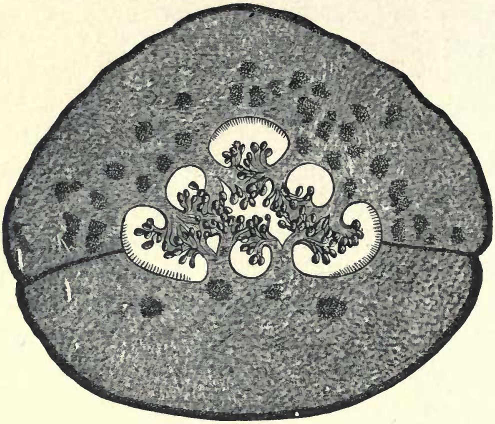

FIG. 490. Vanilla (*Vanilla planifolia*). Cross section of fruit. ×8. (BERG.)

prepared. It has also been found in Siam benzoin and in raw beet sugar. Synthetic vanillin is now made in large quantities from oil of cloves.

HISTOLOGY.

The beans, after soaking in water, serve for studying not only the macroscopic structure, but for cutting microscopic cross-sections and preparing surface mounts.

Pericarp. 1. *The Epicarp* (Figs. 491 and 492, *ep*) consists of thick-walled, finely porous cells, 40–80 μ in diameter, arranged in longitudinal rows. Small stomata of elliptical, often nearly circular, form occur sparingly. In cross-section a thin, yellow cuticle is evident. Brown bodies (10 μ) embedded in a granular ground substance, also short prismatic crystals of calcium oxalate, and less often crystals of vanillin, are the cell-contents.

2. *The Hypoderm Cells* are larger and thicker-walled than those of the epicarp. They are more or less collenchymatously thickened and longitudinally elongated and have distinctly beaded walls. In Mexican, Panama, Honduras, and some other Central American varieties, the pores are greatly elongated, usually spirally, less often longitudinally or transversely, giving the tissue a highly characteristic appearance. This peculiar structure is not found in Bourbon, South American, or the other common varieties, the pores being either round or oval.

3. *Mesocarp* (Figs. 491 and 493, *p*). This is a loose parenchyma of large, thin-walled cells often 150 μ in diameter, with dark-colored contents. Here and there narrow but elongated cells, commonly arranged end to end in longitudinal rows, contain large bundles of extraordinarily long raphides of calcium oxalate reaching 500 μ in length, which, in the preparation of the specimen, are often broken into short pieces. They are best seen after treating tangential sections with alkali. To demonstrate the presence of vanillin, mount a cross-section in 5 per cent phloroglucin solution and draw a drop of sulphuric acid under the

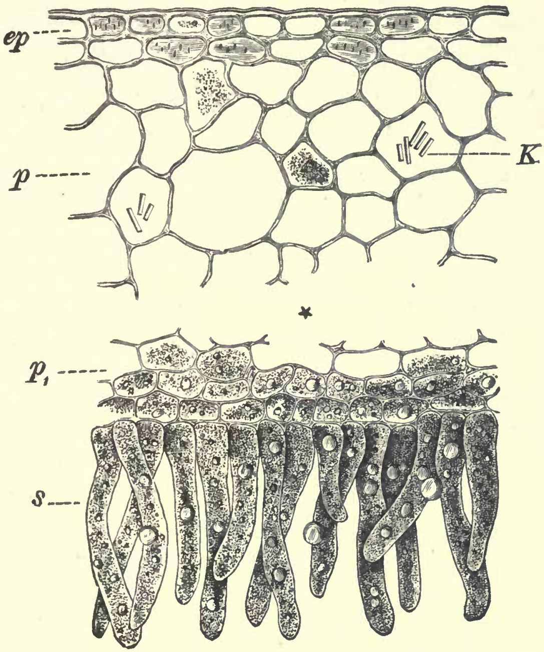

FIG. 491. Vanilla. Cross section of pericarp. *ep* epicarp; *p* mesocarp with *K* crystals; p_1 inner layers of mesocarp; *s* papillæ of endocarp. ×160. (MOELLER.)

cover-glass. A magnificent carmine color appears immediately. The numerous bundles running through the mesocarp are of the collateral or endogenous type, consisting of spiral and reticulated vessels, jointed porous elements, sieve tubes, and bast fibers. Tschirch and Oesterle have noted that the pores of the latter are oval and are not accompanied by the diagonal fissures characteristic of most bast fibers. The cells of the inner mesocarp are smaller than in the outer and middle layers.

4. *The Inner Epidermis* between the three pairs of placentæ bears numerous thin-walled, glandular papillæ (*s*) about 300 μ long, filled with

balsam. Tschirch and Oesterle find that the secretion is formed between the cuticle and the cell-wall proper. The epidermis on the placentae is

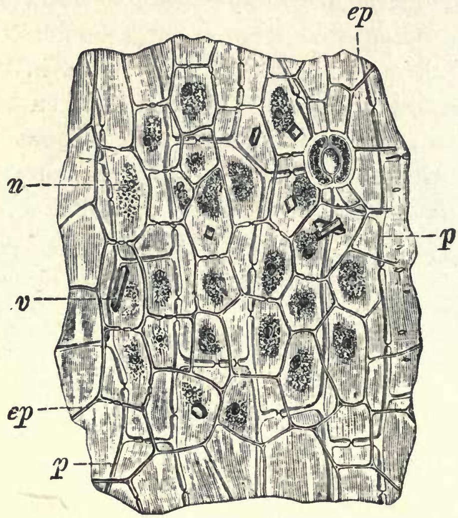

FIG. 492. Vanilla. Outer layers of fruit in surface view. *ep* epicarp with *v* crystals of calcium oxalate; *p* parenchyma. ×160. (MOELLER.)

of thin-walled, elongated elements. On the surface between the members of each pair of placentæ, the epidermal and subepidermal layers

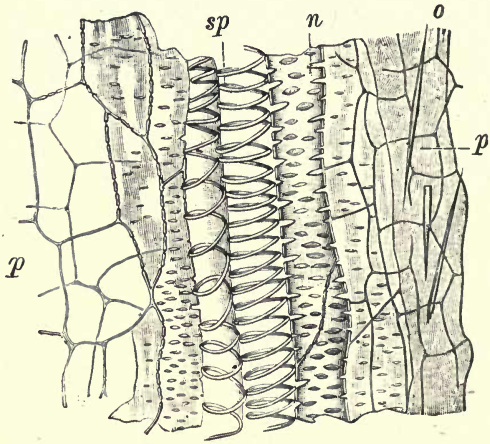

FIG. 493. Vanilla. Longitudinal section of fruit flesh. *p* parenchyma with *o* raphides; *sp* spiral vessel; *n* pitted vessel. ×160. (MOELLER.)

are made up of longitudinal bundles of thread-like mucilaginous cells which serve as a conducting tissue for the pollen tubes. They have been studied by Busse, Tschirch, and others.

Spermoderm (Fig. 494). The exceedingly minute black seeds (less than 0.5 mm. long and about two-thirds as broad) have been aptly com-

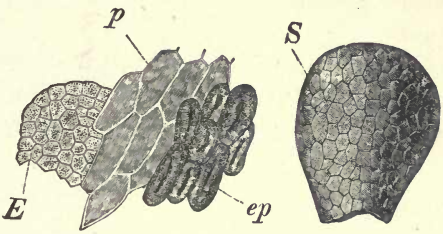

FIG. 494. Vanilla. Elements of seed. *S* whole seed, under a lens; *ep* epidermis; *p* parenchyma; *E* embryo. (MOELLER.)

pared by T. F. Hanausek to gunpowder. Owing to the dark-colored pigment in the spermoderm, the seeds must be boiled with alkali and crushed before any structure whatever is evident.

1. *The Outer Epidermal Cells* (*ep*) are polygonal, 15–30 μ broad and reach 75 μ in length. After boiling with alkali, they are still dark brown, but are sufficiently transparent to show that the cavity is reduced to a narrow slit, owing to the thickened outer and side walls.

2. *The Inner Layers* (*p*) are of elongated, parenchymatous cells, which, like those of the epidermis, are of a brown color.

Embryo (*E*). The endosperm being absent, the kernel of the seed consists entirely of the embryo, which is usually undeveloped.

DIAGNOSIS.

Whole Vanilla seldom reaches the consumer, but is used by manufacturers and apothecaries in the preparation of tincture or extract of vanilla. Although the vanilla may not be of the grade represented, or may have been previously robbed of a portion of its flavoring principles, the fruits themselves cannot be successfully imitated. Chemical means must be resorted to for the detection of Perù balsam, benzoic acid, and other materials with which the fruits are sometimes treated, also to secure evidence of exhaustion. Substitution of Pompona vanilla or the fruits of other inferior species may be detected by macroscopic examination.

Ground Vanilla is an article of commerce used by some manufacturers, who find it more easily extracted than the whole fruit. A preparation of the ground fruit with sugar is also on the market for domestic use. Both of these are subjects for microscopic examination. In certain dry preparations, no vanilla product at all is present, the flavor being due to artificial vanillin or coumarin, or both. In such cases the absence of the histological elements of true vanilla is established by microscopical examination, and the presence of vanillin or coumarin is determined by chemical analysis.

The identification of vanilla in powder form requires great care on the part of the microscopist. The balsam papillæ (Fig. 491, *s*), although the most characteristic of the fruit tissues, owing to their delicate structure, are seldom found intact in the powder. By far the greater part of the fruit flesh is of parenchyma with no distinctive characters, which, like the epidermis, might easily be confounded with the corresponding tissues of other fruits. Of value in identification are the exceedingly long, although often broken, raphides (Fig. 493, *o*), also in lesser degree the elements of the bundles (Fig. 493, *sp*, *n*).

Whole seeds (Fig. 494, *S*) occur in large numbers in the ground product. After boiling with alkali, the epidermal cells (*ep*) are recognized by their brown color and thick walls.

Tonka beans (p. 273) are detected by their characteristic palisade cells and column cells.

Vanilla Extracts are grossly adulterated with tonka-bean extract, synthetic vanillin, and coumarin, caramel being employed to imitate the appearance of the genuine extract. Obviously the detection of these forms of adulteration falls to the chemist and not the microscopist.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Berg (3); Hanausek, T. F. (10, 16, 48); Macé (26); Meyer, A. (27); Moeller (29, 30, 32); Molisch (33); Planchon et Collin (34); Schimper (37); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (43, 45).

BUSSE: Studien über die Vanille. Arb. Kaiserl. Ges. 1898, **15**, 1.

HARTWICH: Ueber die Frucht der *Vanilla Guianensis*. Ber. pharm. Ges. 1895, **5**, 381.

JELLIFFE: Vanilla, Microscopy of Fruit. Journ. Pharm. 1898, **5**, 35.

TSCHIRCH: Die Tela conductrix der Vanillefrucht. Schw. Woch. Chem. Pharm. 1889.

VANILLON.

The fruits of *Vanilla pompona* Schiede, known in the trade as pompona or La Guayra vanilla, also as vanillon, are shorter than those of genuine vanilla (maximum length 15 cm.) and much thicker (maximum 25 mm.). Their odor is different from true vanilla, resembling more that of the tonka bean and benzoin. The pods of Guiana vanilla (*V. Guyanensis* Split.) are as long as the genuine, but three or four times as broad, while those of palm vanilla (*V. palmarum* Lindl.), also obtained from Guiana, are but 5 cm. long and 15 mm. broad. Of these only pompona vanilla is of commercial importance.

HISTOLOGY.

This species is characterized by the large cells of both the pericarp and hypoderm. The epicarp cells (Fig. 495) are about 400 μ long and

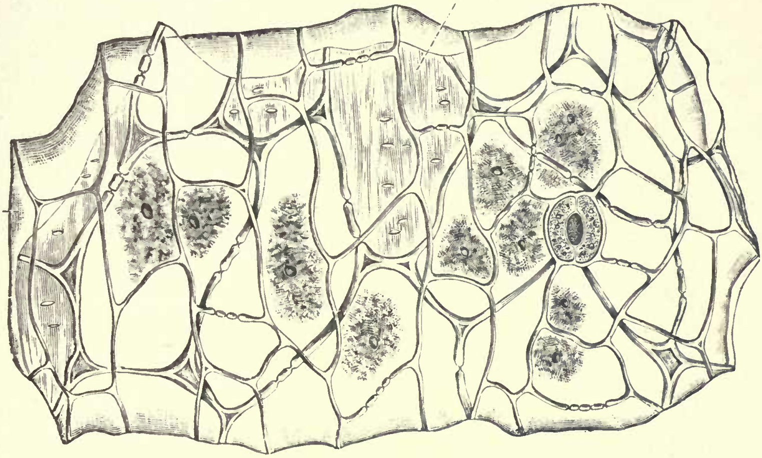

FIG. 495. Vanillon (*Vanilla Pompona*). Surface view of *ep* epicarp and *p* hypoderm. ×160. (MOELLER.)

150 μ broad; the stomata, however, are small (60 μ). Even larger than the epicarp cells are those of the hypoderm, which never have spirally elongated pores.

BAYBERRY.

The bay-tree or laurel of the ancients (*Laurus nobilis* L., order *Lauraceæ*) is still grown in the Levant. It should not be confused with *Myrica acris* Schwarz, the leaves of which are used for the preparation of bay rum.

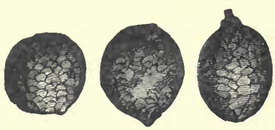

FIG. 496. Bayberries (*Laurus nobilis*), natural size.

The dried fruit (Fig. 496) is ovate or globular, 8–12 mm. in diameter, lustrous, dark brown or green, with numerous wrinkles on the surface. It has a brittle shell, consisting of united pericarp and spermoderm, within which is an embryo with two fleshy cotyledons.

HISTOLOGY.

Pericarp (Fig. 497). 1. The *Epicarp* (*epi*) consists of small polygonal cells with a reticulated cuticle, and occasional stomata.

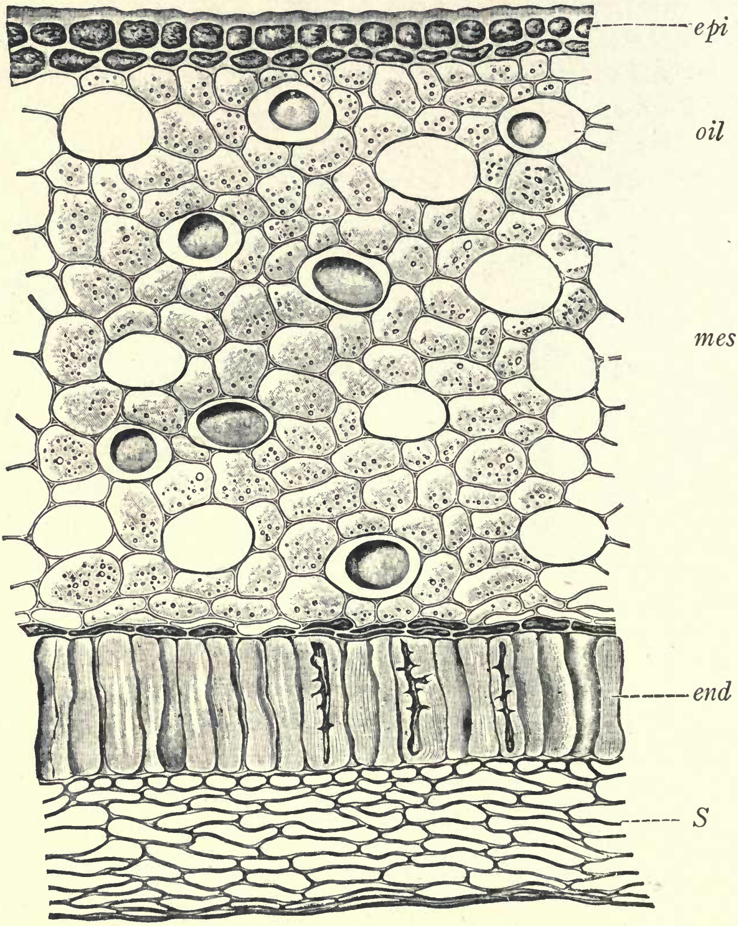

FIG. 497. Bayberry. Shell in cross section. Pericarp consists of *epi* epicarp; *mes* mesocarp with *oil* oil cells, and *end* endocarp; *S* spermoderm. (MOELLER.)

2. *Hypoderm.* This consists of small cells similar to those of the epicarp.

3. *Mesocarp* (*mes*). Numerous oil cells (*oil*) are distributed through the parenchymatous ground tissue. They contain either essential oil or resin.

4. *Endocarp* (*end*). The colorless stone cells are radially elongated

upward of 80 μ high. In surface view they are deeply sinuous in outline (Fig. 498).

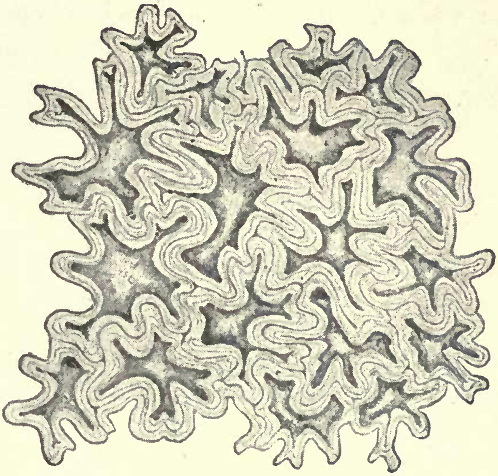

FIG. 498. Bayberry. Endocarp in surface view. (MOELLER.)

Spermoderm (Fig. 497, *S*). The cells are thin-walled, and more or less compressed. Through this tissue pass the raphe and its branches.

Embryo (Fig. 499). The epidermal cells are small; those further inward larger (up to 100 μ). Most of the cells contain starch grains

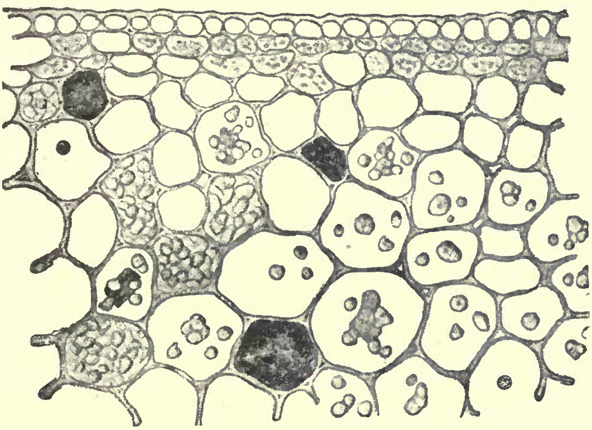

FIG. 499. Bayberry. Cotyledon in cross section, showing starch grains. (MOELLER.)

up to 8 μ, occurring singly or in small aggregates; some however are filled with colorless essential oil.

DIAGNOSIS.

The palisade stone cells of the endocarp, sinuous in surface view (Fig. 498), and the small starch grains (Fig. 499) are the important elements.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Moeller (30, 31); Planchon et Collin (34); Vogl (45).

JUNIPER BERRY.

The juniper (*Juniperus communis* L.) is a well-known forest tree growing in Europe, Asia, and America. It does not, like most gymnosperms, bear a cone, but a round berry about the size of a large blueberry, which it further resembles in having a bloom of a gray-blue color. Strictly speaking, it is not a fruit. At the time of fertilization the three ovules, like those of all other gymnosperms, are naked in the axils of bracts; but during a later stage of development the bracts close about the ovules and coalesce at the edges, forming the globular berry (Fig. 500).

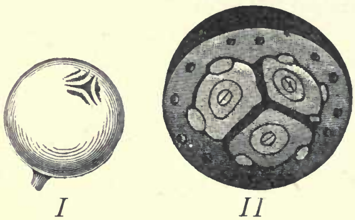

FIG. 500. Juniper Berry (*Juniperus communis*). *I* surface view, natural size. *II* cross section, enlarged. (TSCHIRCH.)

At the apex of the berry three radiating lines mark where the three bracts meet, while midway between these lines the small extremities of the bracts are evident as three minute protuberances.

Tschirch and Oesterle observe that these berries are morphologically closely related to true fruits, the chief difference being that in the latter the metamorphosed leaves which form the ovary are united from the first, whereas in the former this union does not take place until after fertilization. Each seed is united with the fruit on the outer side except at the apex, but is free on the inner side. The fruit has an agreeable resinous odor and taste.

HISTOLOGY.

Dried juniper berries, as obtained from the apothecary, may be used for studying the gross anatomy of the fruit, also the microscopic structure of the principal tissues, although more satisfactory results are obtained with fresh berries, especially if picked at different stages of ripeness.

For convenience, the tissues are here designated by the same terms as are employed for true fruits.

Pericarp (Fig. 501). *The Epicarp Cells* (Fig. 502, *ep*) in surface view are rounded polygonal, with thick walls pierced here and there by pores. Division into daughter cells is often apparent. A brown granular substance fills the cells. On the edges where the bracts meet, these epidermal cells are extended so as to form blunt papillæ.

2. *Fruit Flesh* (*p*). The rounded, sac-like cells of the ground tissue are so loosely united that they separate readily on pressing with the cover-glass. In this tissue are large resin cavities often 1 mm. broad and twice as long, lined on the inner surface by a layer of secreting cells. On

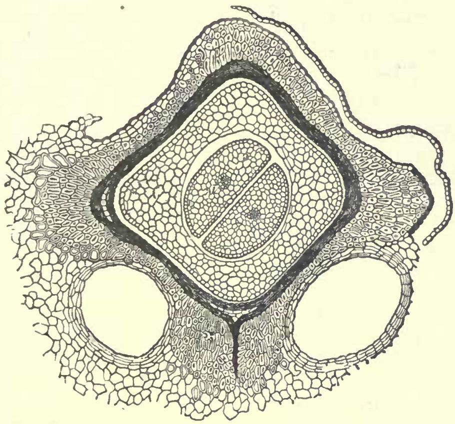

FIG. 501. Juniper Berry. Cross section of seed, and enveloping tissues. (TSCHIRCH.)

removing the angular seeds from the fruit, one or more of these sacs filled with solid resin often remain attached to the surface. The conspicuous elements of the fibro-vascular bundles are numerous bast fibers and reticulated vessels, also a few spiral vessels.

Spermoderm. On the outer side where the seed is united with the fruit flesh no demarcation between the tissues of the two is evident; but on the free inner surface there are five distinct layers.

1. *The Outer Epidermis* and 2. *The Subepidermal Coat* each consists of a single layer of thin-walled cells, the former separating readily from the latter in cross-section.

3. *Sclerenchyma* (Fig. 502, *sc*). The dense stone-cell tissue varies in thickness from two to over ten cell layers. Each of the thick-walled,

porous stone cells contains in its narrow cavity a beautiful crystal of calcium oxalate.

4. *Compressed Cells* form the fourth layer, and

5. *An Inner Epidermis* of longitudinally elongated, thin-walled cells completes the spermoderm.

Perisperm. This is a thin membrane of several layers of parenchyma,

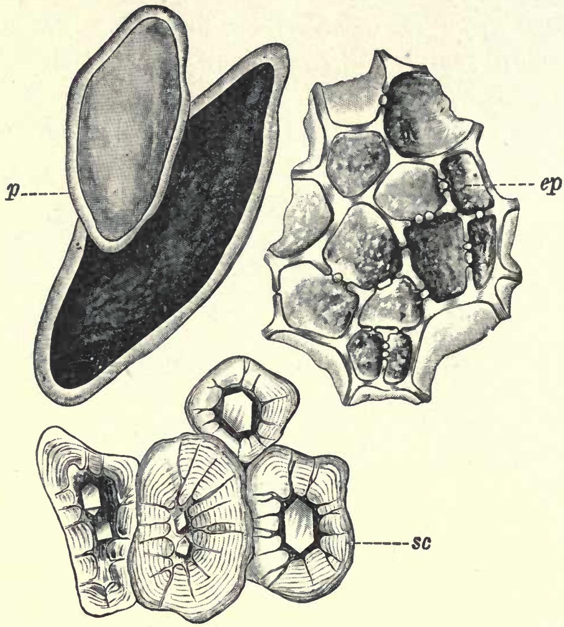

FIG. 502. Juniper Berry. Elements in surface view. *ep* epicarp; *p* cells from fruit flesh; *sc* stone cells with crystals, from spermoderm. (MOELLER.)

of which only the longitudinally-elongated cells of the outer layer are well preserved.

Endosperm. Tschirch and Oesterle have noted that the outer wall of the outer cell layer consists of: (1) an outer cuticularized lamella of minute rod-like elements appearing granular in surface view; (2) a yellow middle lamella, also cuticularized, and (3) an inner membrane of cellulose. The endosperm cells contain aleurone grains up to 8 μ and fat.

The Embryo is axially located and consists of a radicle about 2 mm. long and two flattened cotyledons about half the length of the radicle. The cell-contents are the same as those of the endosperm.

DIAGNOSIS.

Juniper berries are used in medicine and very extensively in making gin. The residue from the distilleries is a pepper adulterant.

The epicarp cells (Fig. 502, *ep*), especially the papillæ from the sutures, the rounded pulp cells (*p*), and the stone cells (*sc*) of the spermoderm each containing a crystal, are the elements worthy of special notice.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Meyer (24); Moeller (28, 29); Planchon et Collin (34); Tschirch u. Oesterle (37); Villiers et Collin (39).

BARKS.

The only barks of importance as food products are cinnamon, cassia, and a few others used occasionally as spices.

All of these contain conspicuous stone cells and most of them characteristic starch grains, also bast fibers and cork cells.

The general structure of barks is discussed on p. 40.

CASSIA (CINNAMON).

Cassia (known in retail trade as cinnamon) is the bark of various species of *Cinnamomum* (order *Lauraceæ*).

Three leading sorts, each with distinct physical characters, are recognized by English and American importers: (1) China or Canton, (2) Batavia, and (3) Saigon.

Malabar, Indian and other cassias are of comparatively small importance.

China or Canton Cassia, the *Cassia lignea* of the pharmacists, is the commonest and also the cheapest grade. The average wholesale price is about half that of Batavia and one-fifth that of Saigon. The tree from which it is obtained (*C. Cassia* Bl., *C. aromaticum* Nees.) is a small evergreen growing in southeastern China. The commercial bark is unscraped or only partially scraped, brown-gray, 0.2–3.0 mm. thick, more or less convolute. It is commonly packed in mats containing two bundles about 50 cm. long, weighing 1 kg. each. The outer part of the bundles consists of long pieces, the inner part of chips and often a considerable amount of dirt. Broken cassia or chips consisting of short pieces with more or less dirt and other impurities is packed in bales.

Winton, Ogden and Mitchell found in samples of whole China cassia from American importers 3.01–5.58 per cent of ash and 0.93–1.64 per cent of essential oil. One sample of chips obviously unfit for consumption contained 20 per cent of ash and 15.7 per cent of sand.

Batavia Cassia is probably obtained from *C. Burmanni* Bl. The tightly-rolled quills are light buff or red-brown, 0.5–2 mm. thick, often 50–75 cm. long. Light-colored thread-like bast-fiber groups are evident on close inspection of the outer surface. This grade is distinguished from China and Saigon by the slimy, glutinous mass formed on treatment of the powdered material with water, also by the higher percentage of alcohol extract (11–17 per cent). The flavor is moderately pungent and distinctly mucilaginous.

Saigon Cassia, the most pungent and expensive of all cassia and cinnamon barks, is obtained from a tree grown in Cochin-China, stated to be *C. Loureirii* (*Laurus cinnamomum* Lour.). The bark varies from a fraction of a millimeter to over 5 mm. in thickness; the thin being chocolate-brown, the thick, gray-brown. Usually it is put up in bundles about 30 cm. long, and weighing 1.5–2 kg., each consisting entirely of thick, medium or thin bark. Broken Saigon (chips) often contains pieces 5–10 mm. thick.

The samples examined by Winton, Ogden and Mitchell contained on the average over 4 per cent of essential oil, and in some cases over 5 per cent.

Malabar Cassia and Cassia Vera are terms loosely applied to inferior grades of uncertain origin.

Indian Cassia comes into the market in small amount from Travancore and other regions.

HISTOLOGY.

Transverse and longitudinal sections are readily cut after soaking over night in water. These, as well as the powdered material, are examined directly in water (noting especially the starch grains) and again after treatment with alkali.

China Cassia. 1. *The Epidermis,* which is found only in young bark is strongly cuticularized.

2. *Cork* (Fig. 503, *su*). The cells of the outer layers are of the usual thin-walled type, those further inward are stone cork with uniformly thickened porous walls, while those in the layer adjoining the phellogen are thickened on the outer and radial sides in such a manner as to form

in cross-section a series of arches. The pnellogen or active layer is recognized by the thin walls. Brown contents are often present in the cork cells, particularly those with thick walls.

3. *Cortex* (*cor*). The ground parenchyma is of flattened cells with

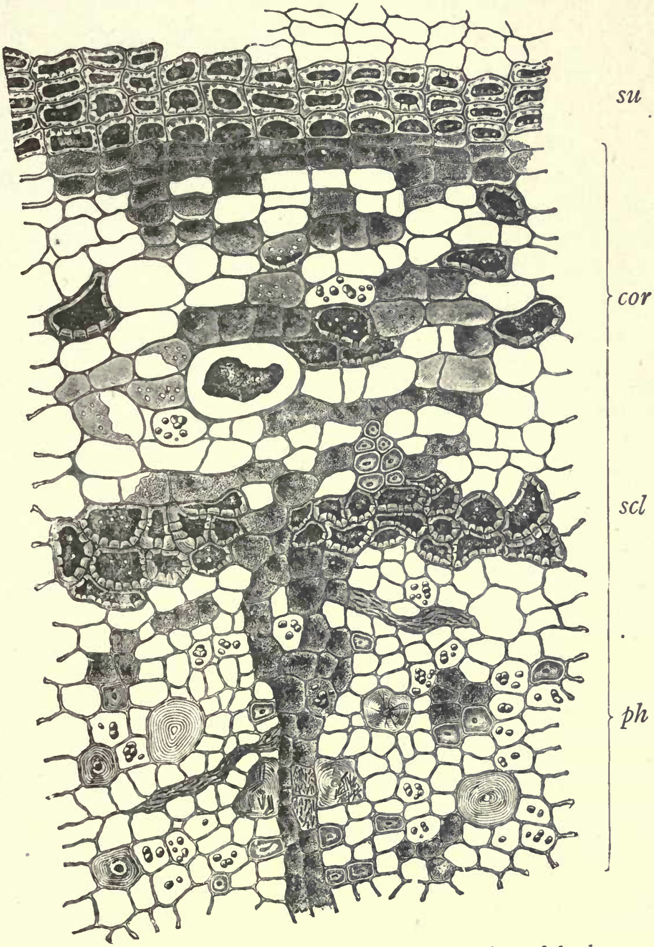

FIG. 503. China Cassia (*Cinnamomum Cassia*). Cross section of bark. *su* cork cells; *cor* cortex; *scl* stone-cell ring (pericycle); *ph* bast. (MOELLER.)

rather thick, brown walls. Radial partitions often divide the cells into daughter cells. Distributed through this ground tissue are stone cells, many of which are thickened only on the inner side. Both the parenchyma and the stone cells contain rounded starch grains (Fig. 505, *B*) ranging up to 20 μ in diameter (mostly over 10 μ), with a more or less distinct hilum. Most of the grains are in aggregates of 2–4 individuals

4. *The Pericycle* (*scl*) in the young stem consists of groups of bast fibers (Fig. 504, *b*) and separating parenchyma, but later numerous stone

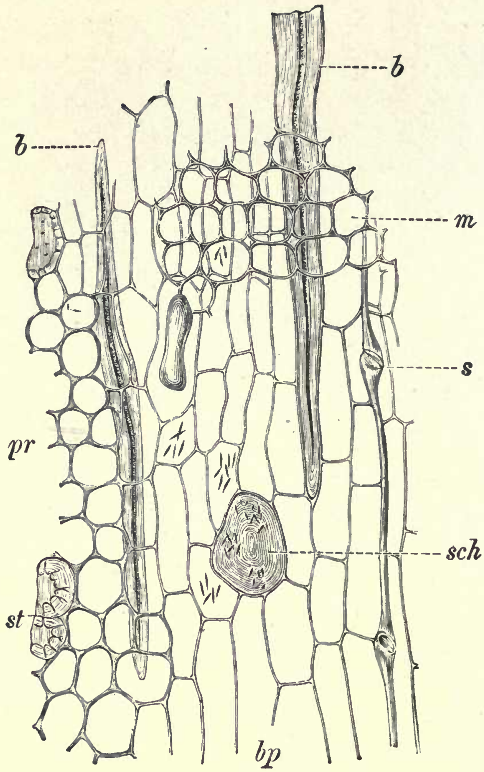

FIG. 504. China Cassia. Radial longitudinal section of bark. *pr* parenchyma of cortex; *bp* parenchyma of bast; *b* bast fibers; *st* stone cells; *sch* mucilage cells; *s* sieve tubes; *m* medullary rays. ×160. (MOELLER.)

cells are formed, which after a time make up the greater part of the ring. The bast fibers are longer and thinner-walled than those of the bast; the stone cells are larger and thicker-walled than those of the cortex.

5. *The Bast Zone* (*ph*), as seen in cross-section, consists of broad radial bands of phloem elements separated by narrow medullary rays. The ground tissue of the phloem is a parenchyma of narrow, longitudinally elongated cells, among which are distributed larger cells containing mucilage or oil, also bast fibers. Numerous starch grains like those of the cortex occur in the parenchyma. The inner membrane of the oil

cells secretes essential oil and resin, which either forms brown masses in the cells or impregnates the tissues. Sections mounted in glycerine or alcohol often show the thick, colorless, stratified secondary membrane of the mucilage cells, which dissolves on addition of water. Characteristic of the bast fibers are their moderate length (seldom over 600 μ), spindle shape, thick homogeneous walls, and narrow cavity. In the middle they vary up to 45 μ in diameter. The sieve tubes are collapsed and are arranged in tangential rows. The medullary rays are usually two cells broad except at the more or less funnel-shaped outer ends. They contain starch grains and numerous oxalate needles.

Batavia Cassia, being scraped, contains little cork and cortex tissues. The mucilage cells, though rather small, are numerous. The most characteristic elements are the starch grains, which are smaller (usually less than 10 μ) and less numerous than those of China and Saigon, and the numerous oxalate crystals, chiefly in the medullary rays, which, as may be seen after treatment with alkali, are tabular or prismatic, not needle-shaped. These characters, with the peculiar taste and the slimy mass formed on treating the powder with water, are well marked.

Saigon Cassia. The thin bark has practically the same structure as that of China cassia; the thick bark (2–10 mm.) is characterized by the presence of large, tangentially elongated, thick-walled stone cells of the bast, which are arranged side by side in enormous radial groups, often 1–2 mm. long. Two or more cork systems, each with its phellogen, are often present.

DIAGNOSIS.

Whole Cassia of the three common sorts may be distinguished by the general appearance and the characters given in the following analytical key:

(*a*) Needle-shaped crystals in medullary rays; starch grains abundant, mostly over 10 μ; alcohol extract under 10%.
1. Few or no stone cells in bast; flavor mild; essential oil under 2%......China.
2. Numerous stone cells in bast of thick bark; very pungent; essential oil 2–6%. Saigon.

(*b*) Prismatic crystals in medullary rays; starch grains not abundant, mostly under 10 μ; alcohol extract over 10%.
3. Flavor mild, distinctly mucilaginous; essential oil under 3%........Batavia.

It should be remembered that the microscopic characters of the thick and thin bark are somewhat different, and that the chemical composition is changed by exhaustion.

Other species of *Cinnamomum* yielding inferior barks are occasionally substituted for real cinnamon. One of these described by Micko closely resembled Batavia cassia in its structure as well as its mucilaginous properties, but was scarcely at all pungent.

Ground Cassia (**"Cinnamon"**) may be prepared from one variety of cassia, or from a mixture of several varieties, often with the addition of cassia buds. The conspicuous elements common to all the cassia barks are rounded starch grains (Fig. 505, *B*), usually in aggregates of 2

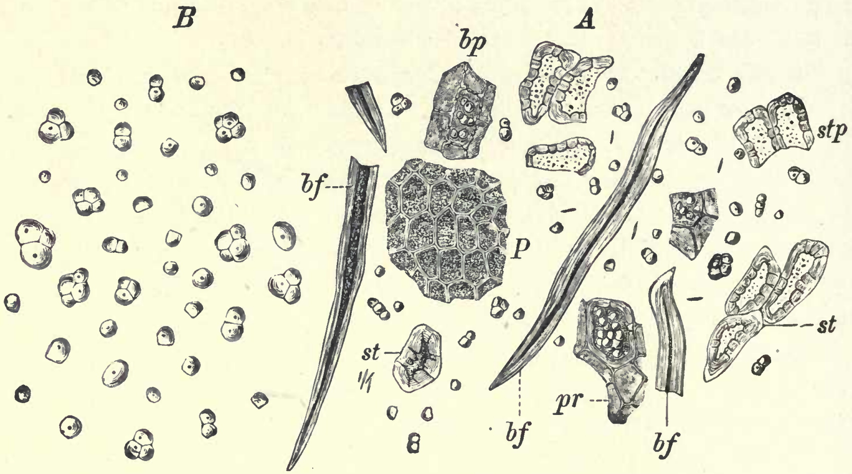

FIG. 505. China Cassia. *A* elements of the powdered bark: *bf* bast fibers; *st* pericycle stone cells; *stp* cortex stone cells; *pr* cortex parenchyma; *bp* bast parenchyma; *P* sclerenchymatized cork. ×160. *B* starch grains, ×600. (MOELLER.)

to 4; spindle-shaped bast fibers (*bf*) with narrow lumen; stone cells (*st*), often thickened only on one side (*stp*); and brown parenchyma. Cork cells (*P*) are present if the bark is unscraped. Oxalate needles (China, Saigon) or prisms (Batavia) may be seen on careful examination. All the elements named but the starch grains are best studied after treatment with alkali.

The elements of cassia buds are described in the following section.

Adulterants. Exhausted cassia; cassia chips, containing wood, leaves, and dirt; bran; biscuit; millet; oil cakes; nutshells; foreign barks; sawdust; mineral matter.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Berg (3); Greenish (14); Hanausek, T. F. (10, 16); Hassall (19); v. Höhnel (48); Leach (25); Macé (26); Meyer, A. (27, 28); Moeller (29, 30, 31, 32); Planchon et Collin (34); Schimper (37); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (43, 45).

BISCHOFF: Vjschr. öffent. Gesundheits. 1870, **22**, 395.
GARNIER: Étude microscopique et chimique de diverses poudres de cannelle. Jour. Pharm. **9**, 473.
GICHARD: Verfälschung von Zimmtrindenpulver. Ztschr. Nahr.-Unters. Hyg. 1895, **9**, 281.
HANAUSEK, T. F.: Chips. Ztschr. österr. Apoth.-Ver. 1896, 34.
HARTWICH: Beiträge zur Kenntniss des Zimmt. Arch. Pharm. 1901, 181.
MALFATTI: Eine neue Verfälschung des Zimmtpulvers. Ztschr. Nahr.-Unters. Hyg. 1891, **5**, 5.
MICKO: Ueber eine falsche Zimmtrinde. Ztschr. Unters. Nahr.-Genussm. 1900, **3**, 305.
PERROT: Sur l'origine de l'anneau sclereux des canelles. Jour. pharm. chim. 1890, **2**, 426.
PFISTER: Zur Kenntniss der Zimmtrinden. Forschber. Lebensm. Hyg. 1894, **1**, 1.
PFISTER: Zur Zimmtuntersuchung. Forschber. Lebensm. Hyg. 1894, **1**, 540.
SCHMITZ-DUMONT: Ueber eine vermeintliche Zimtfälschung. Ztschr. öff. Chem. 1904.

CASSIA BUDS.

The flowers of a Chinese tree (probably *Cinnamomum Cassia* Bl., which also yields cassia bark), gathered shortly after blooming, are known in commerce as cassia buds. They are dark brown, woody, club- or top-shaped, 5–10 mm. in diameter, with a short stem or pedicel. The perianth forms a wrinkled, urn-shaped capsule, turned in at the top, in which is the lighter-colored, thick, smooth, one-celled ovary. In the small circular opening between the six indistinct perianth lobes is the smooth exposed surface of the ovary with the style or its scar.

HISTOLOGY.

The **Pedicel,** or flower stem, may or may not be attached to the bud. It should not be confused with the narrow under portion of the perianth.

1. *The Epidermis* consists of strongly cuticularized cells, with colorless walls, similar to the epidermal cells of cloves, and thick-walled, often crooked, unicellular hairs, seldom over 120 μ long (Fig. 506, *h*).

2. *Cortex.* In the outer layers this is made up of large parenchyma cells and oil cells; in the inner layers, of smaller cells. The parenchyma has brown walls and contains small ovate or spindle-shaped simple starch grains and needles of calcium oxalate. The oil cells often have mucilaginous contents.

3. *Sclerenchyma Ring* (Pericycle). The elements are bast fibers and stone cells. The bast fibers are in closely crowded groups. Some are broad, blunt, unicellular, with broad cavities (*f*), others sharp-pointed

and jointed (*bf*). Both forms are very different from the bast fibers of the bark. The stone cells (*st*) in cross section appear much like the bast fibers, but are usually larger (up to 90 μ). They are irregular in form, and often thickened more on one side than on the other.

(4) *Bundles.* The vessels are narrow (15 μ), mostly reticulated or scalariform, less often spiral, and are arranged in radial rows.

(5) *The Pith* is narrow.

Perianth. This has much the same structure as the pedicel, but the xylem and phloem are more separated, and the pith in the basal part

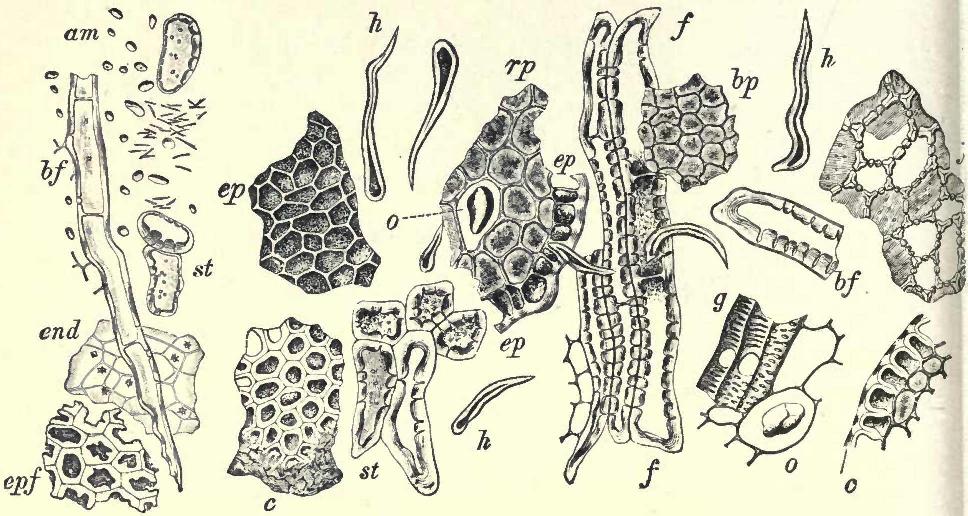

FIG. 506. Cassia Buds (*Cinnamomum Cassia*).

Elements of pedicel: *bf* bast fibers; *f* elongated sclerenchyma cells; *st* stone cells; *g* vessels; *st* starch.

Elements of perianth: *ep* epidermis; *h* hairs; *rp* cortex parenchyma; *o* oil cells; *bp* bast parenchyma.

Elements of ovary: *epf* epicarp in cross section and surface view, with *c* cuticle; *fp* sclerenchyma of mesocarp; *end* endocarp.

×160. (MOELLER.)

is much broader. The cortex parenchyma has rather thick walls and red-brown contents, becoming blue with iron chloride. The oil cells are 30–80 μ in diameter, and contain red-brown resinous oil. A colorless, mucilaginous parenchyma with small crystal rosettes and occasional large crystals forms the inner epidermis of the cavity.

Ovary. The epicarp (*epf*) is well developed on the smooth, yellow, exposed surface. The cuticle is thick, and penetrates between the cells, giving them the appearance of being thick-walled. It is distinguished from the brown cell walls by its lighter color. Beneath the epidermis is a layer of sclerenchyma (*fp*). The seeds are undeveloped.

DIAGNOSIS.

Ground cinnamon often contains both cassia bark and cassia buds. The buds cost more than China and Batavia cassia, and are more pungent. Several elements serve to distinguish the buds from the bark: (1) thick-walled crooked hairs (Fig. 506, *h*); (2) reticulated and scalariform vessels; (3) broad, blunt bast fibers (*f*) with broad cavities; (4) jointed fibers (*bf*). Hairs and vessels are not found in the bark, and the bast fibers are of a very different type. The bark has no tissues like the epidermal layers of the pedicel, perianth (*ep*) and ovary (*epf*). The sclerenchyma of the ovary (*fp*) is also characteristic. Stone cells of much the same type occur in both the bark and the buds. The starch grains of the buds are not in aggregates as in the bark, but are not distinguishable from the single grains of the latter.

BIBLIOGRAPHY.

See Cassia, p. 590.

CEYLON CINNAMON.

True cinnamon is obtained from the young branches of *Cinnamomum Ceylonicum* Breyne, a small tree cultivated in Ceylon and parts of India. The bark is carefully separated from the branches, scraped, dried, and the thin pieces, scarcely 0.5 mm. thick, are curled one within another so as to form sticks, 5–15 mm. in diameter and often 1–2 meters long. On the outer surface the scraped bark is buff, streaked with lighter-colored bast-fiber bundles. The flavor suggests a mixture of cassia and calamus.

HISTOLOGY AND DIAGNOSIS.

In structure cinnamon (Fig. 507) closely resembles cassia, but the stone cells of the pericycle are longer and more uniformly thickened, the bast fibers are narrower and more numerous, the parenchyma cells of the bast are smaller, and the starch grains are only about half as large (usually 6–8 μ). The resemblance between cinnamon and Batavia cassia in these details is much closer, particularly as regards the starch grains, which are practically identical in the two species. Unlike Batavia, but like China cassia, the crystals in the bast are needle-shaped.

Fortunately it is seldom necessary to resort to microscopic examination, as the product is usually sold whole, and can be readily identified by its general appearance and its peculiar flavor.

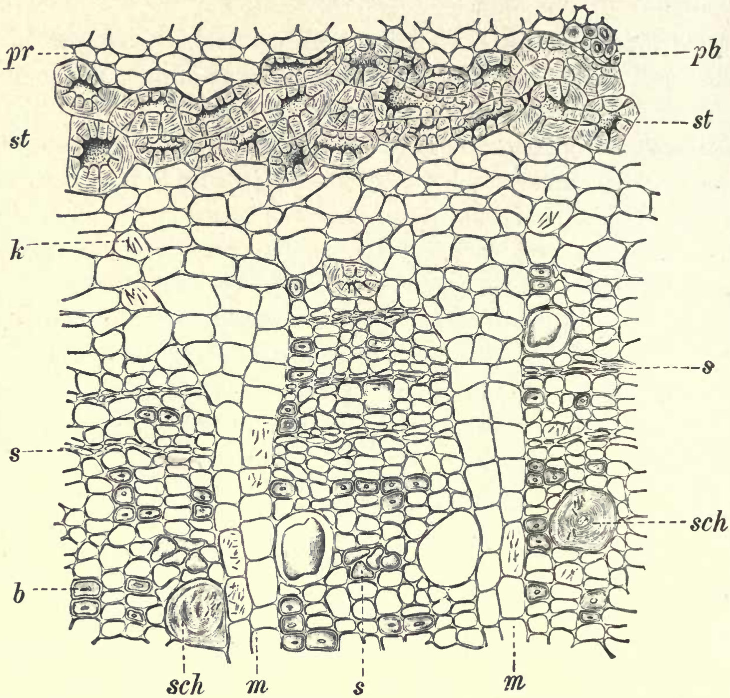

FIG. 507. Ceylon Cinnamon (*Cinnamomum Ceylonicum*). Cross section of bark. *pr* inner layers of cortex with *pb* primary bast-fiber bundle; *st* stone-cell ring (pericycle); bast consists of *b* bast fibers, *s* sieve tubes, *sch* mucilage cells, *k* parenchyma with raphides, and *m* medullary rays. ×160. (MOELLER.)

BIBLIOGRAPHY.

See Cassia, p. 590.

CLOVE BARK.

The bark of a small Brazilian tree (*Dicypellium caryophyllatum* Nees., order *Lauraceæ*) is variously known as clove bark, clove cassia, clove cinnamon, and (in pharmacy) *Cortex cassiæ caryophyllatus*. Like Ceylon cinnamon it comes into the market in compound quills. The bark is 1–2 mm. thick, more or less flaky on the outer surface, finely striate on the inner. It is brittle, and breaks with a smooth fracture. Cross sections examined with the naked eye show a thin yellow outer ring and a broad inner zone with yellow dots in a red-brown ground.

HISTOLOGY.

1. *Cork.* The cells in most of the layers are thin-walled, but in two or more layers are thickened on the outer side. Only traces of the cork tissue are found on the commercial bark.

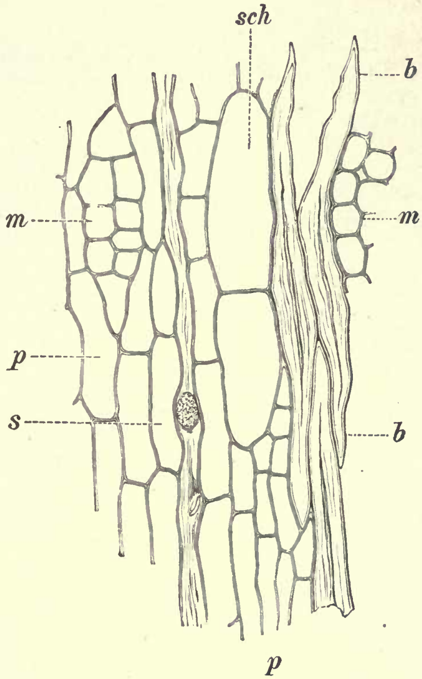

FIG. 508. Ceylon Cinnamon. Tangential section of bark. *p* bast parenchyma; *sch* mucilage cells; *b* bast fibers; *s* sieve tubes; *m* medullary rays. ×160. (MOELLER.)

2. *Phelloderm* (Fig. 509, *P*). The inner walls of the cells are strongly thickened and porous.

3. *Cortex.* The tissue is of parenchyma cells with a few oil cells.

4. *Pericycle.* A ring of stone cells (*st*) thickened chiefly on the inner side separates the cortex from the bast.

5. *Bast.* Tangential layers of parenchyma cells with occasional oil cells (*oe*) alternate with groups of sieve tubes (*s*). In old bark the parenchyma is replaced here and there by stone-cell groups (*sc*). Bast fibers are absent. The primary medullary rays broaden greatly at the outer ends, separating the phloem into wedge-shaped groups, which extend as far as the pericycle. The parenchyma of the bast and the

medullary rays contains numerous oxalate needles, also formless lumps of starch.

DIAGNOSIS.

Starch occurs only in small amount and not in well-formed grains. The cells of the pericycle (Fig. 509, *st*) and phelloderm (*P*), both thickened

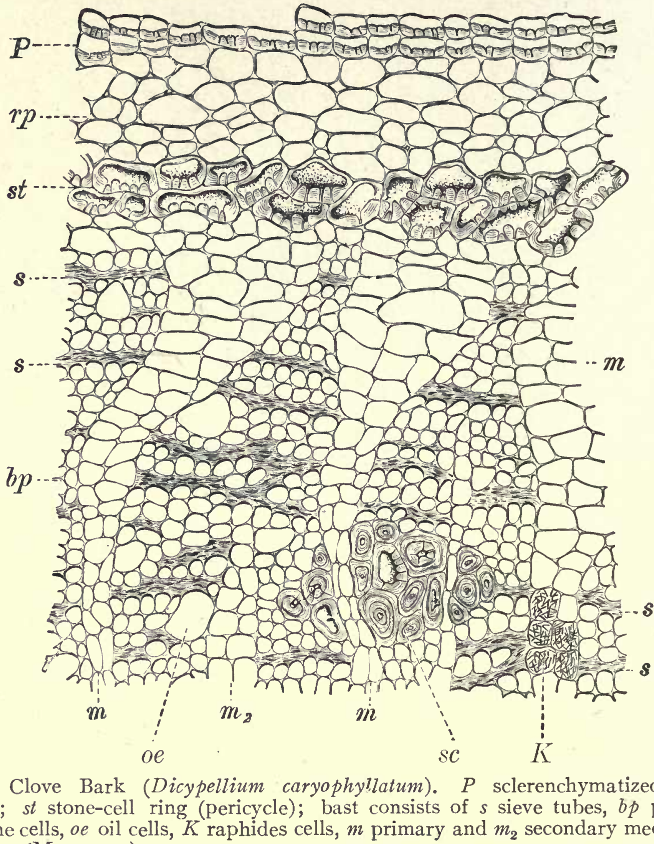

FIG. 509. Clove Bark (*Dicypellium caryophyllatum*). *P* sclerenchymatized cork; *rp* cortex; *st* stone-cell ring (pericycle); bast consists of *s* sieve tubes, *bp* parenchyma, *sc* stone cells, *oe* oil cells, *K* raphides cells, *m* primary and m_2 secondary medullary rays. ×160. (MOELLER.)

on one side, also the oil cells and oxalate needles, are evident after treatment with alkali.

Vogl describes a substitute which he regards as a variety of *Cinnamomum Culilawan*. The structure is much like that of other species of cinnamon.

Another substitute described by Moeller, known as *Cortex caryophyllata* (Fig. 511), is characterized by the intensely red-brown contents of the parenchyma elements, and the tangential rows of fibers in the bast.

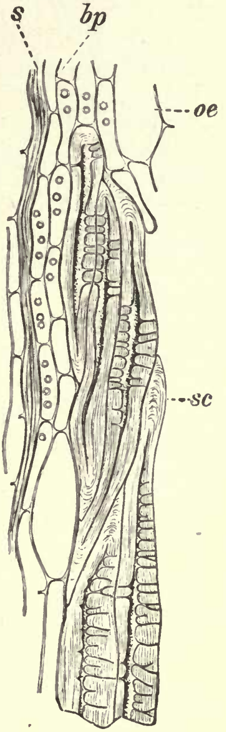

FIG. 510. Clove Bark. Radial longitudinal section through a stone-cell group of the bast. *sc* stone cells; *oe* oil cells; *bp* bast parenchyma; *s* sieve tubes. ×160. (MOELLER.)

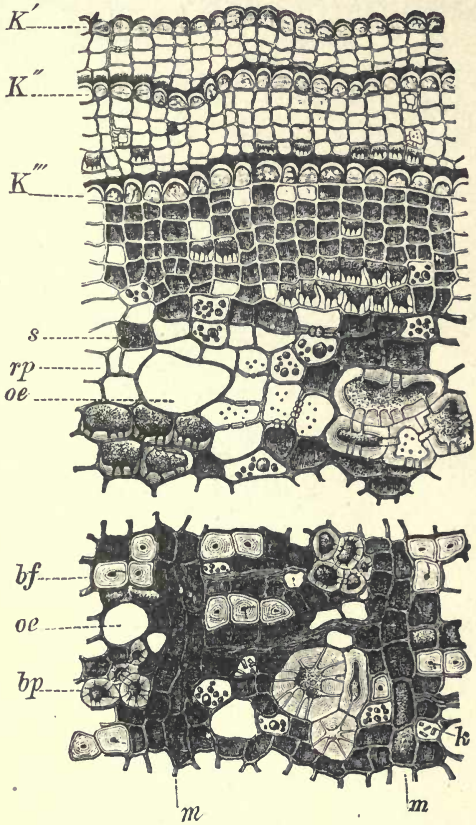

FIG. 511. False Cinnamon ("*Cortex caryophyllata*"). Cross section of bark. *K′*, *K″*, *K‴* three layers of cork; *rp* cortex parenchyma with *oe* oil cell and *s* crystal sand cell; *bf* bast fibers; *bp* sclerenchymatized bast parenchyma; *k* crystal cell; *m* medullary rays. (MOELLER.)

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Moeller (26); Planchon et Collin (34); Tschirch u. Oesterle (37); Vogl (41).

CANELLA BARK.

Canella alba Mussay (order *Canellaceæ*) grows wild in the West Indies and Florida. The bark, known as white bark or white cinnamon, is a well-known drug, the commercial supply coming largely from the Bahama Islands. It is also used in the West Indies as a spice.

The bark is hard, 2–5 mm. thick, light buff or reddish, pitted on the outer surface, striated on the inner. In cross section numerous yellow oil cells are evident, also in the inner bark delicate radiating lines.

HISTOLOGY.

1. *Cork* (Fig. 512, *K*). Typical cork cells form the outer layers of the bark.

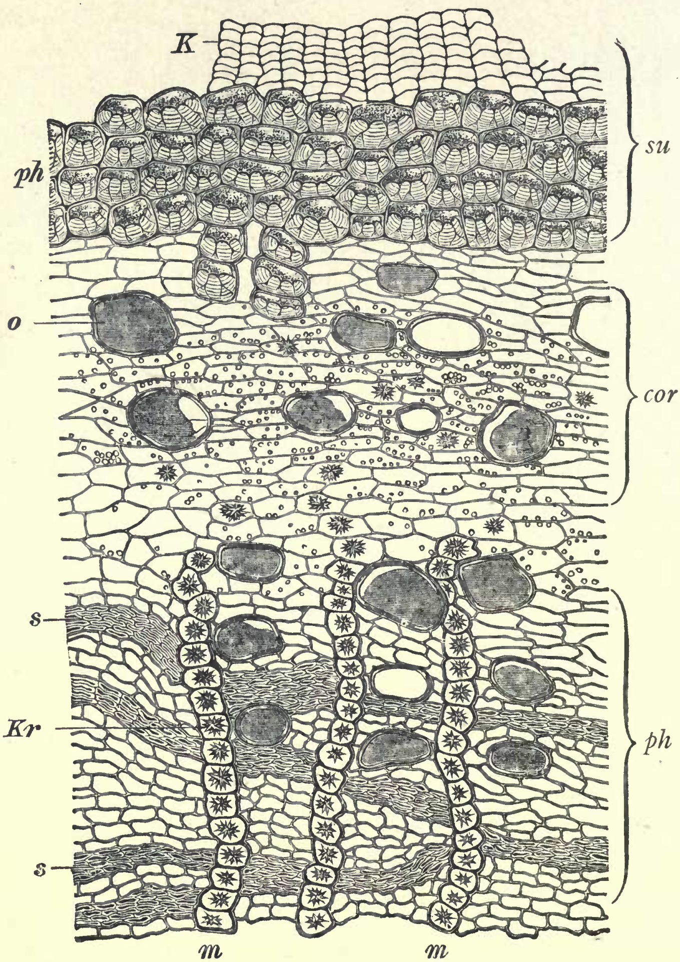

FIG. 512. Canella Bark (*Canella alba*). Cross section. *su* outer bark consists of *K* cork and *ph* sclerenchymatized cork; *cor* cortex with starch cells, and *o* oil cells; *ph* bast with *s* sieve tubes and *m* medullary rays containing *Kr* crystal rossettes. (TSCHIRCH.)

2. *The Phelloderm* (*ph*), separated by the phellogen from the outer cork, consists of several layers of quadrilateral stone cells intermixed with cork-like cells, all arranged in radial rows.

3. *Cortex* (*cor*). The parenchyma contains simple or compound starch grains, mostly 6–8 μ (maximum 20 μ), also rosettes of calcium oxalate. Large oil cells with rather thick cuticularized walls occur here and there.

4. *Bast* (*ph*). Tissues like those of the cortex, also sieve tubes and single-rowed medullary rays (*m*) are conspicuous. An oxalate rosette occurs in nearly every medullary cell. Bast fibers are found only between the primary and secondary bast, and there but sparingly.

DIAGNOSIS.

The large yellow oil cells (Fig. 512, *o*), the yellow sclerenchymatized cork cells (*ph*) of the phelloderm, the small starch grains, and the oxalate rosettes are the important elements. Sieve plates are often evident in the sieve tubes. Bast fibers are almost entirely absent.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Hanausek, T. F. (10); v. Höhnel (48); Planchon et Collin (34); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (45).
GREENISH: Canella Bark, Pharm. Jour. 1894.

RHIZOMES.

The rhizomes of Zingiberaceous plants (ginger, turmeric, zedoary, and galangal) contain about half their weight of starch in the form of large elongated grains with excentric hilum and distinct rings. Reticulated vessels are notable elements.

Sweet flag, the only other rhizome of importance as a spice, contains very small rounded starch grains.

The general structure of rhizomes is discussed on p. 44.

GINGER.

The ginger plant (*Zingiber officinale* Roscoe, order *Zingiberaceæ*), a native of Southern Asia, is cultivated throughout the tropics. The rhizomes (so-called roots) are dug in January or February, washed and sun-dried either directly or after scraping. They are often bleached with chlorinated lime or sulphurous acid, also coated with chalk or gypsum. Chalk not only improves the appearance of the product, but in addition protects it from the ravages of the drug-store beetle and other insects. The rhizomes are flattened somewhat, and branched on one or both of the narrow sides. They vary in breadth from 10–25 mm. and in length up to 10 cm. The fracture is uneven, with protruding fibers. Cross sections examined under a lens show numerous yellow oil cells.

Jamaica, the finest sort, has a rather slender rhizome. It is commonly bleached, and often coated in addition. The rhizomes of Cochin are thicker, and come into the market either scraped or bleached. Calcutta and African are unscraped sorts, distinguished from the preceding by their dark-colored corky rind. Japan resembles Cochin in appearance, but is usually obtained from other species (*Z. Zerumbet* Roscoe, *Z. Cassumunar* Rxb., *Z. Mioga* Roscoe, *Z. Cemenda* Rxb., etc.).

HISTOLOGY.

1. *Cork.* In a rind 0.4 mm. thick about 20 cell-layers are present. The cells are large, somewhat flattened, and have thin brown walls, but no content.

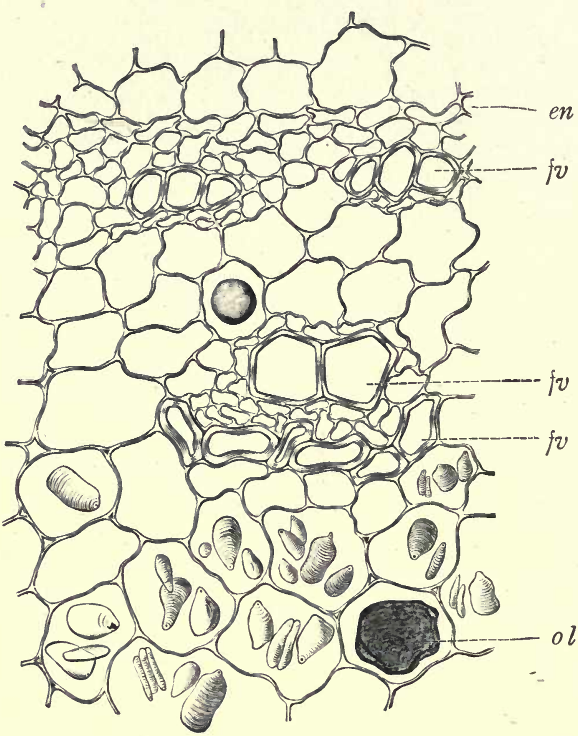

FIG. 513. Ginger (*Zingiher officinale*). Cross section of rhizome. *en* endodermis; *fv* fibro-vascular bundles; *oil* oil cell. (MOELLER.)

2. *Cortex.* Inside the cork zone is a zone of about the same thickness, consisting of small collapsed parenchyma cells interspersed with

oil cells. Further inward the parenchyma cells are larger, and contain numerous starch grains while the oil cells are less abundant. The contents of each oil cell are contracted into a resin lump. Bundles occur sparingly in the cortex.

3. *Endodermis* (Fig. 513, *en*). The cells resemble transversely elongated parenchyma cells, but their walls are suberized, and they contain no starch.

4. *Bundle Zone* (*fv*). Inside the endodermis the bundles are arranged close together in a circle. The vessels are broad (50 μ), with reticulated

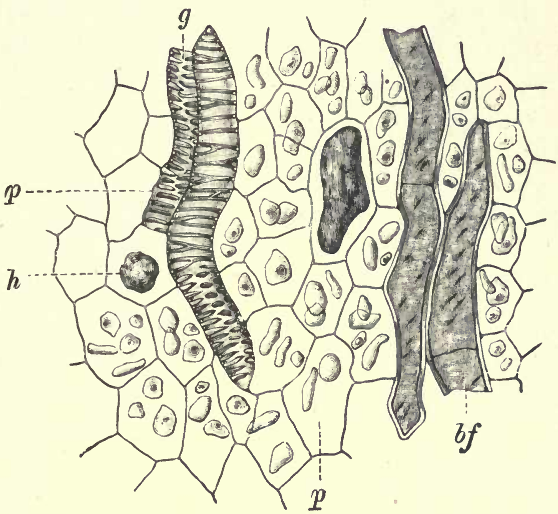

FIG. 514. Ginger. Longitudinal section of rhizome. *h* oil cells; *p* starch parenchyma; *g* vessels; *bf* bast fibers. ×160. (MOELLER.)

or scalariform thickenings (Fig. 514, *g*). They are accompanied by long (up to 6 mm.), broad (up to 60 μ) fibers, often divided by cross partitions into compartments. The walls are rather thin, and have pores crossed by diagonal fissures.

5. *The Parenchyma* cells, like those of the inner cortex, are closely packed with starch grains. Oil cells (*oil*) occur here and there.

The starch grains (except in Japan ginger) are simple, flattened, ovate, with either a rounded angle or a tapering point at the smaller end. Being flattened, they appear narrow when viewed on edge. The excentric hilum is always in the pointed end. Rings are numerous, but indistinct. Most of the grains are 20–30 μ long, although smaller grains as well as larger (up to 50 μ) occur sparingly. T. F. Hanausek was the first to note that the starch grains in Japan ginger (or at least certain kinds known under that name) are very different from the type. They are partly large, simple, broadly ovate, with very distinct rings, and partly small, in twins, triplets, and larger aggregates. The small grains are particularly numerous.

DIAGNOSIS.

Ground Ginger prepared from African and Calcutta rhizomes is brown, while that prepared from Jamaica, Cochin, Japan, and other scraped or bleached sorts is white or light buff. The chief elements are the characteristic starch grains (which make up fully half of the powder), reticulated or scalariform vessels (Fig. 514, *g*), broad bast fibers (*bf*) with rather thin walls, and, in the case of undecorticated sorts, cork cells. Large ovate starch grains (Fig. 513) with excentric hilum in the rounded-angular or pointed, smaller end occur in all varieties; small grains in twins, triplets, and larger aggregates only in Japan ginger.

The common adulterants are exhausted ginger, cereal products, linseed meal, and other ground oil cakes, nutshells, gypsum, and other mineral substances. In America rice bran, consisting of spermoderm with more or less starchy matter (p. 110), is often used.

Exhausted Ginger is the residue after treatment with water in the manufacture of ginger ale or after exhaustion with alcohol for the preparation of ginger extract. In the former case the product is deficient in cold-water extract, in the latter case it is deficient in alcohol extract. Microscopic examination is of no service in detecting these residues.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Berg (3); Hassall (19); Macé (26); Meyer, A. (10, 27); Moeller (29, 30, 31, 32); Planchon et Collin (34); Schimper (37); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (43, 45, 48).

BARTHELAT: Tanninzellen der Zingiberaceen. Jahr. Pharm. 1894.

BUCHWALD: Ingwer. Arb. Kais. Gesundh. 1899, **15**, 229.

HANAUSEK, T. F.: Eine neue Ingwersorte. Ztschr. allg. österr. Apoth.-Ver. 1883, 465.

MEYER, A.: Ueber die Rhiz. d. offic. Zingiberaceen. Arch. Pharm. 1881, 401.

TSCHIRCH: Zur Untersuchung von *Rhiz. Zingiberis* und *Rhiz. Zedoarie.* Schw. Woch. Pharm. Chem. 1905.

TURMERIC.

Curcuma, or turmeric, is the rhizome of *Curcuma longa* L. (order *Zingiberaceæ*), a plant closely related to ginger, grown in India, China, Cochin China, Java, and other tropical countries.

The main rhizome (round turmeric) is ovate or pear-shaped, up to 4 cm. long and 3 cm. thick (Fig. 515). The upper part is encircled by leaf-scars, the lower part is marked by scars of the secondary rhizomes and roots. It is sliced before drying. The secondary rhizomes (long turmeric) are 0.5–1.5 cm. thick, elongated, indistinctly ringed, simple or sparingly branched.

The vitality of the rhizomes is destroyed by scalding previous to drying, thus converting the grains into lumps, to which the mixture of oil and

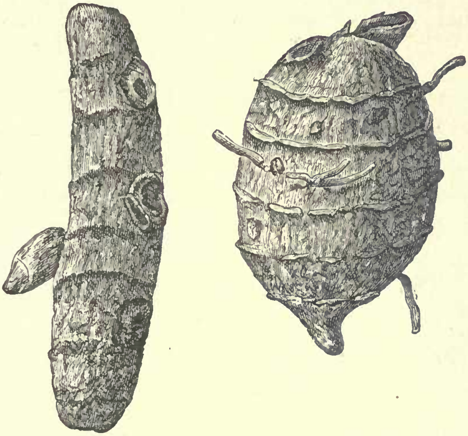

FIG. 515. Turmeric (*Curcuma longa*). Primary (round) and secondary (long) rhizomes. (HAGER.)

curcumin liberated from the oil cells imparts a deep-yellow color. As found on the market, the product is hard, tough, and sinks in water. The fractured surface is smooth, waxy, of an orange-yellow color. As appears in cross section, the rind is thicker than in ginger, constituting almost one-quarter of the thickness of the rhizome. It cannot be removed by scraping.

HISTOLOGY.

Turmeric (Fig. 516) closely resembles ginger in structure, but is distinguished by the absence of bast fibers. The epidermis, which in parts is well preserved, resembles that of *Curcuma Zedoaria*, and like the latter bears thick-walled unicellular hairs. The yellow lumps (*h*), consisting largely of starch-paste, are colored blue by iodine. On addition of dilute alkali the yellow coloring substance (curcumin) with which they are impregnated becomes brown-red. Concentrated sulphuric acid imparts a crimson color. In addition to the starch lumps, perfect starch grains are often present. These resemble the grains of ginger, but are usually longer (65 μ) and narrower, although some are broader than long. The parenchymatous ground tissue, as well as the oil cells, is colored deep yellow. Neither the vessels (g) nor the cork-cells (K) are characteristic.

DIAGNOSIS.

Turmeric has a characteristic pungent taste, and must be classed as a spice as well as a coloring substance. Curry powder is a mixture of turmeric, pepper, ginger, coriander, cardamoms, cloves, allspice, cara-

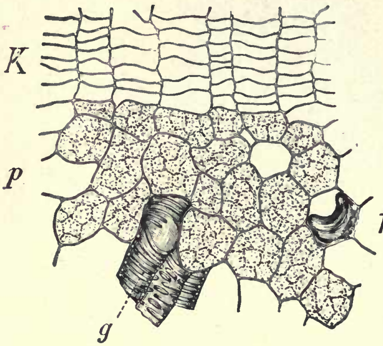

FIG. 516. Turmeric. Cross section of rhizome. *K* cork; *p* parenchyma filled with starch paste; *h* oil cell; *g* vessel. ×160. (MOELLER.)

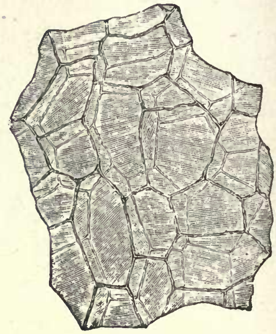

FIG. 517. Turmeric. Cork cells in surface view. ×160. (MOELLER.)

way, and fenugreek. Aside from its use in the arts, turmeric is extensively employed for coloring mustard, noodles, and other food products, often with the purpose of deceiving the consumer.

It is detected by the yellow starch lumps, which become red-brown with alkali, crimson with strong sulphuric acid, and blue with iodine. The vessels are like those of ginger; bast fibers, however, are not present. A piece of filter-paper impregnated with a concentrated alcoholic extract of the material and dried gives on moistening with a dilute solution of boric acid (containing in each 10 cc. about six drops of concentrated hydrochloric acid) and drying, a cherry-red color, becoming deep blue with ammonia.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Greenish (14); Hanausek, T. F. (16, 17); Leach (25); Macé (26); Meyer, A. (27); Moeller (29, 30, 31, 32); Planchon et Collin (34); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (45).

ZEDOARY.

The zedoary plant (*Curcuma Zedoaria* Roscoe, order *Zingiberaceæ*), although belonging in the same genus as turmeric, has much larger rhizomes, which are cut into transverse or longitudinal slices before drying. The rind is easily removed by scraping. Numerous oil cells are evident in cross section.

HISTOLOGY.

The structure (Figs. 518 and 519) resembles that of ginger and turmeric. Like the latter, the epidermis, with thick-walled or unicellular

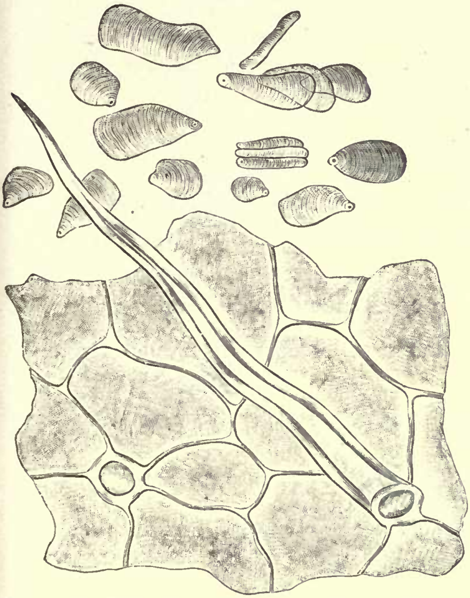

FIG. 518. Zedoary (*Curcuma Zedoaria*). Epidermis and starch grains of rhizome. (MOELLER.)

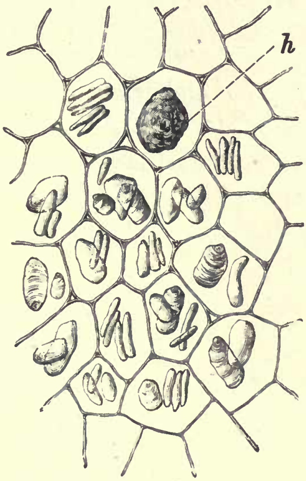

FIG. 519. Zedoary. Parenchyma of rhizome showing starch grains and *h* resin lump. × 160. (MOELLER.)

hairs, is here and there well preserved. The cork cells are large and thin-walled. Although the starch grains are of the same type as those of turmeric, they are distinguished by their more rounded form and more uniform size (maximum 80 μ). Many of the grains are ovate, with scarcely any evidence of a point. Bast fibers are absent.

DIAGNOSIS.

Zedoary is now seldom used either as a spice or a drug outside of the countries where it is produced. It has a milder taste than turmeric, with a suggestion of camphor. The powder (Figs. 518 and 519) resembles ginger in color, but bast fibers are absent.

GALANGAL.

Common or small galangal is the rhizome of *Alpinia officinarum* Hance (order *Zingiberaceæ*), a plant growing on the island of Hainan and the neighboring Chinese coast. *Alpinia calcarata* Roscoe, a closely related species, yields a rhizome used in India. Large galangal, obtained from a Javanese species (*A. Galanga* Sw.), is seldom exported.

The finger-like rhizomes of the common sort are encircled by fringed leaf-scars, and bear also here and there root-scars. They are brown-red inside and out, somewhat hard, and have an uneven fracture. The thickness of the rind exceeds the diameter of the central cylinder. Cross sections are dotted with dark oil cells and light bundles.

HISTOLOGY.

1. *The Epidermis* (Fig. 520, *ep*) consists of small polygonal cells and stomata. T. F. Hanausek notes that several cell-layers are often present. Cork tissue is absent.

2. *Cortex.* In the outer layers the parenchyma cells are small, with thin dark-red walls, and contain a brown substance in granules and

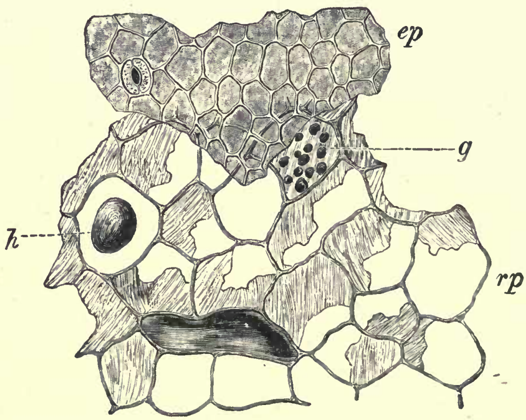

FIG. 520. Galangal (*Alpinia officinarum*). Outer layers of rhizome in surface view. *ep* epidermis; *rp* brown parenchyma; *g* tannin grains; *h* oil cell. ×160. (MOELLER.)

lumps, but no starch. Further inward the cells have thick porous walls, and contain starch grains.

3. *Endodermis* (Fig. 521, *end*). The cells have suberized walls, and

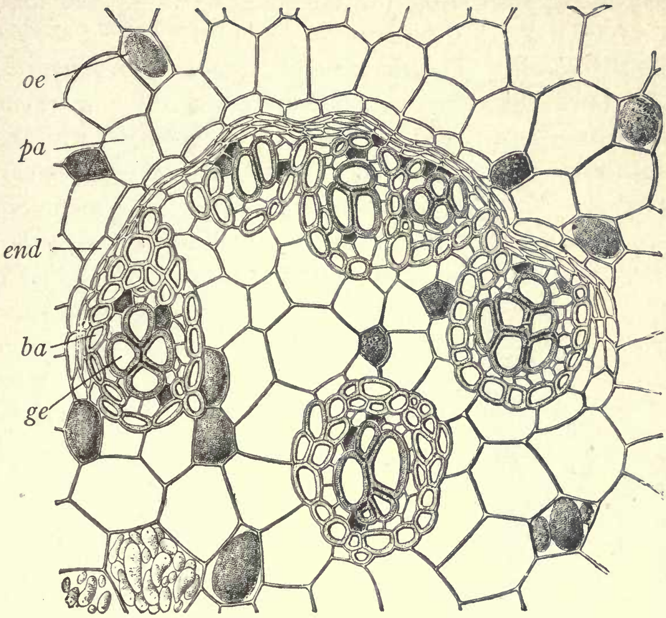

FIG. 521. Galangal. Cross section of rhizome. *pa* parenchyma, *oe* oil cells, and *end* endodermis of the cortex; *ba* bast fibers and *ge* vessels of a bundle. (GILG.)

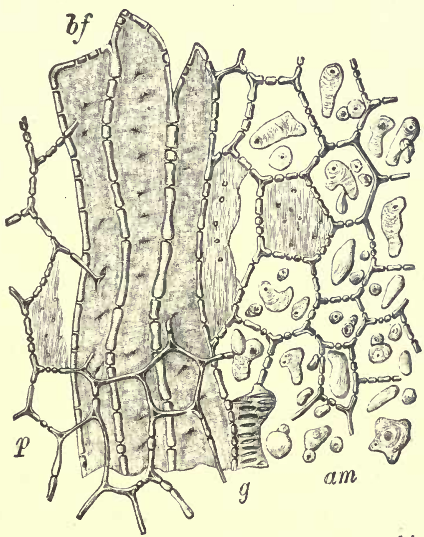

FIG. 522. Galangal. Longitudinal section of rhizome. *p* thick-walled parenchyma; *bf* bast fibers; *g* vessel; *am* starch. ×160. (MOELLER.)

are further distinguished from the adjoining layers by the absence of starch.

4. *Central Cylinder.* The thick-walled, porous parenchyma is usually rich in starch (Fig. 522, *am*), but the grains differ markedly from those of turmeric. As a rule they are simple, club-shaped, with the hilum in the larger end. Curious hammer-shaped and other irregular forms are also present. They are mostly 20–35 μ long, but sometimes exceed 80 μ. Some rhizomes contain no starch. Distributed among the parenchyma cells are typical oil cells with brown contents. The bundles are always accompanied and often surrounded by broad bast fibers with walls of medium thickness (double 12 μ). The vessels are broad (45 μ) and have noticeably thicker walls than the parenchyma.

Fig. 523. Sweet Flag (*Acorus Calamus*). *A* upper side of rhizome, showing leaf scars, internodes, and two stumps of flower stalks. *B* lower side showing root scars. Natural size. (Vogl.)

DIAGNOSIS.

The irregular starch grains (Fig. 522, *am*) with hilum in the broad end, the parenchyma (*p*) with thick porous walls, and the bast fibers (*bf*) are the noteworthy elements.

SWEET FLAG.

The sweet flag, or calamus root, is the dried rhizome of *Acorus Calamus* L. (order *Araceæ*), a plant growing in shallow water and swamps. The scars of the roots form zigzag markings on the under surface (Fig. 523). The undecorticated rhizome is dark red-brown, the decorticated cream-colored.

HISTOLOGY.

1. *Epidermis* (Fig. 524, *ep*). The brown skin consists of polygonal epidermal cells with cork cells on the root scars.

2. *The Hypoderm* cells are collenchymatous, arranged in several layers.

3. *Cortex* (Fig. 525). The collenchyma passes by degrees into a highly characteristic loose parenchyma, consisting of chains of small rounded polygonal starch cells (*s*) and oil cells (*o*) forming a network, with large intercellular spaces (*i*) in the meshes.

The starch grains are rounded, 3–6 μ in diameter, and usually occur singly, seldom in aggregates of 2–4. Accompanying them in the cell

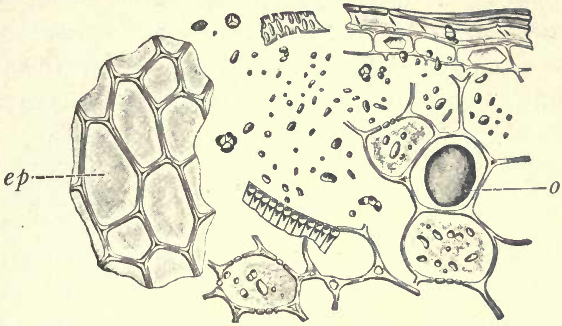

FIG. 524. Sweet Flag. Elements of rhizome. *ep* epidermis; *o* oil cell. (MOELLER.)

are proteid matter and lumps with the reactions of tannin. According to Hartwich the contents of many cells is a substance colored red by aniline and hydrochloric acid.

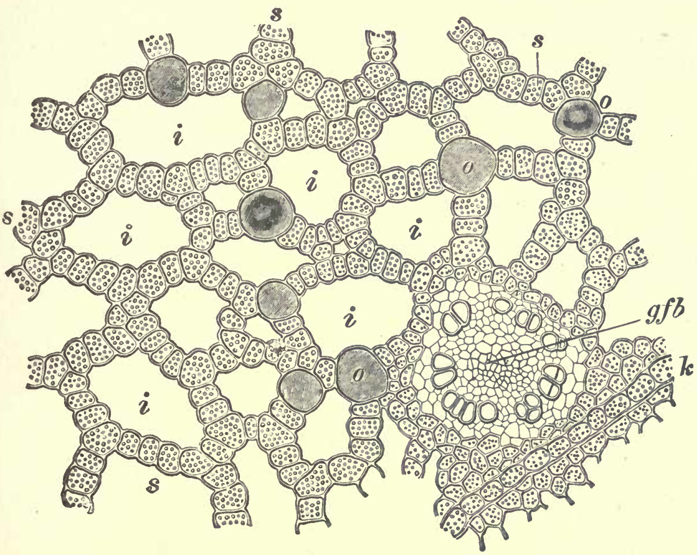

FIG. 525. Sweet Flag. Cross section of rhizome. *s* starch parenchyma forming network about *i* intercellular spaces; *o* oil cells; *gfb* fibro-vascular bundle; *k* endodermis. (TSCHIRCH.)

The oil cells are usually larger than the starch cells (30–90 μ), and occur mostly at the knots of the network. Each contains a drop of yellow oil or a lump of resin, which often falls out from sections. In the outer part of the cortex the bundles consist solely of bast fibers accompanied sometimes by crystal fibers; further inward they are true fibro-vascular bundles of the collateral type with a sheath of bast fibers.

4. *Endodermis.* The cells are suberized, and contain starch.

5. *Central Cylinder.* The ground tissue is a network of starch and oil cells like that of the cortex. The bundles are concentric, with the xylem elements forming a ring about the phloem.

DIAGNOSIS.

The powder contains a large amount of small rounded starch grains (Fig. 524). Chains of starch cells and oil cells (Fig. 525) from the spongy parenchyma are found intact even in the finest powder. The walls separating the starch cells are knotty-thickened, but those adjoining the intercellular spaces are thin, non-porous. Vessels occur in considerable numbers.

BIBLIOGRAPHY.

See pp. 671–674: Moeller (30, 32); Planchon et Collin (34); Tschirch u. Oesterle (40); Vogl (44).

LEAVES.

Of the leaves used as spices, those of labiates, including sage, marjoram, savory, thyme, and hyssop, are the most important. They are characterized by the presence of jointed hairs, multicellular glands and glandular hairs. Bay-leaf has thick-walled, porous, sinuous, epidermal cells. Other leaves of lesser importance are wormwood, tarragon, and sorrel.

The general structure of leaves is discussed on p. 28.

SAGE.

Sage (*Salvia officinalis* L., order *Labiatæ*) grows wild in Mediterranean countries and is cultivated in many regions for use as a drug and pot herb.

The leaves (Fig. 526) are petioled, frequently lobed at the base, ovate to lanceolate, blunt or pointed, finely scolloped, on the surface finely reticulated. When young they are covered with a white or gray felt of hairs, later they become almost smooth.

HISTOLOGY.

The Epidermis (Fig. 527) is much the same on both sides, consisting of polygonal, wavy, or sinuous cells, hairs and stomata, the latter being most numerous on the lower side. In addition to the disk-shaped glands characteristic of labiates are present glands with unicellular or multicellular stems and globular heads divided below by a vertical partition. Characteristic are the whip-like hairs, which are often so abundant as to form a felt. They are very long, narrow, thick-walled, one or more celled, with peculiarly thickened partition walls.

Mesophyl crystals are absent.

FIG. 526. Sage (*Salvia officinalis*). Leaf, enlarged. (MOELLER.)

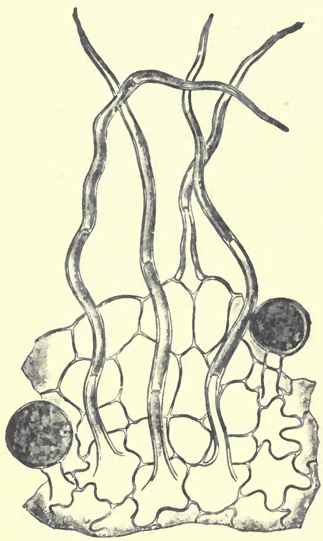

FIG. 527. Sage. Epidermis of leaf with jointed hairs and glands. (MOELLER.)

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Moeller (30, 31, 32); Planchon et Collin (34); Vogl (44).

MEYER, AD.: Off. Blätter u. Kräuter. Halle, 1882.

MARJORAM.

Marjoram (*Origanum Majorana* L., order *Labiatæ*), a native of northern Africa and middle Asia, is a common pot herb in Europe. The dried product consists of the leaves, flowers, and branches.

The leaves (Fig. 528) are petioled, ovate-spatulate, blunt, entire, soft-downy on both sides, with veins forming indistinct loops.

FIG. 528. Marjoram (*Origanum Majorana*). Leaf, natural size. (MOELLER.)

HISTOLOGY.

Epidermis. On both sides the cells have unequally knotty-thickened walls, which on the upper side (Fig. 529) are slightly wavy, on the under side (Fig. 530), deeply sinuous. Small stomata, with two adjacent cells, occur in large numbers on the under surface, sparingly on the upper.

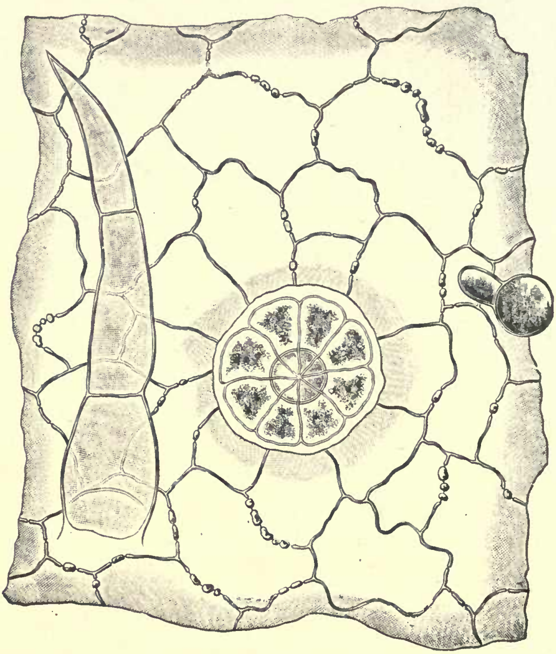

FIG. 529. Marjoram. Upper epidermis of leaf in surface view. (MOELLER.)

Three forms of hairs are found on both sides: (1) long, broad, multicellular, thin-walled, often finely warty hairs, mostly curved at the apex;

(2) glandular hairs with 2–4 celled stalks and 1–2 celled heads; (3) disk-shaped glands with cells arranged in a rosette, about which the epidermal cells also form a rosette.

Mesophyl crystals are absent.

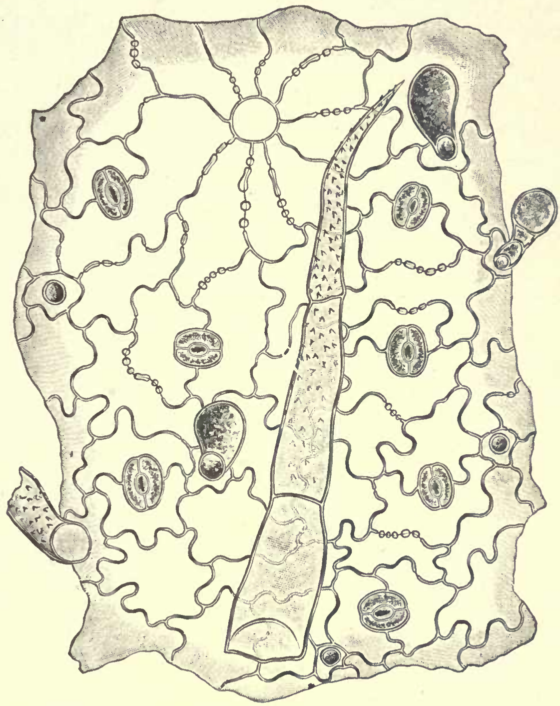

FIG. 530. Marjoram. Lower epidermis of leaf in surface view. (MOELLER.)

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Planchon et Collin (34); Vogl (44).
MEYER, AD.: Off. Blätter u. Kräuter. Halle, 1882.
MITLACHER: Pharm. Post. 1902.

SAVORY.

Savory or summer savory (*Satureja hortensis* L., order *Labiatæ*) is a native of southern Europe, and is cultivated over a wide area. The leaves, flowers, and branches are used dried as a pot herb.

The leaves (Fig. 531) are linear lanceolate, tapering into a short petiole, pointed, entire, with glands on the edges and on both sides. Only the midrib is prominent.

HISTOLOGY.

FIG. 531. Savory (*Satureja hortensis*). Leaf, natural size. (MOELLER.)

The *Epidermis* (Fig. 532) is much the same on both sides. The cell-walls are irregularly sinuous, distinctly porous. The numerous stomata have an adjacent cell at each pole. Hairs occur sparingly and are of three forms: (1) jointed hairs, gradually tapering from the broad base to the apex, with smooth or warty, somewhat thick walls, some very long (visible to the naked eye), of four or more joints, others short, conical, 2–3 celled; (2) typical disk-shaped glands occurring in great numbers in depressions; (3) glandular hairs, with short stalks and globular 1–2 celled heads.

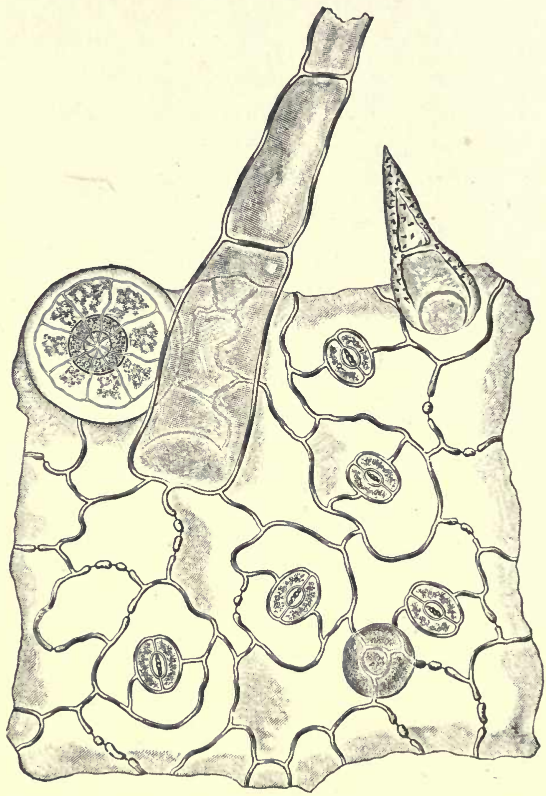

FIG. 532. Savory. Epidermis of leaf in surface view. (MOELLER.)

Mesophyl crystals are absent.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Planchon et Collin (34); Vogl (44).

THYME.

This herb (*Thymus vulgaris* L., order *Labiatæ*) is used both for culinary and medicinal purposes. It is a native of Europe, where it is also cultivated. The leaves are strongly revolute, 10 mm. or less long. Short hairs and brown glands are visible under a lens.

FIG. 533. Hyssop (*Hyssopus officinalis*). Leaf, natural size. (MOELLER.)

HISTOLOGY.

Stomata occur on both epidermal layers. The very numerous hairs are mostly 1–2 celled, short (under 75 μ), conical, distinctly warty. Hairs with globular heads are also present.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Vogl (45).

HYSSOP.

This herb (*Hyssopus officinalis* L., order *Labiatæ*), a semi-shrubby

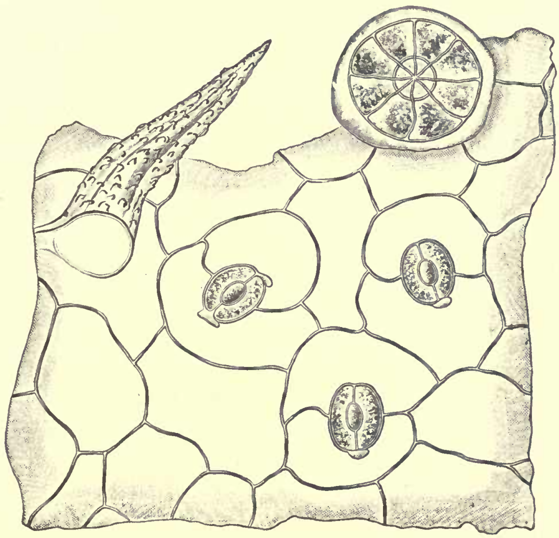

FIG. 534. Hyssop. Upper epidermis of leaf in surface view. (MOELLER.)

plant with small leaves, is a native of southern Europe and a common garden plant in other parts of the Old World.

The leaves (Fig. 533) are sessile, lanceolate, entire, finely reticulated, when dry rolled up and wrinkled on the edges. The side veins are not prominent.

HISTOLOGY.

Epidermis. Stomata, disk-shaped glands, and short unicellular warty hairs are found on both surfaces. The cell-walls on the upper side are

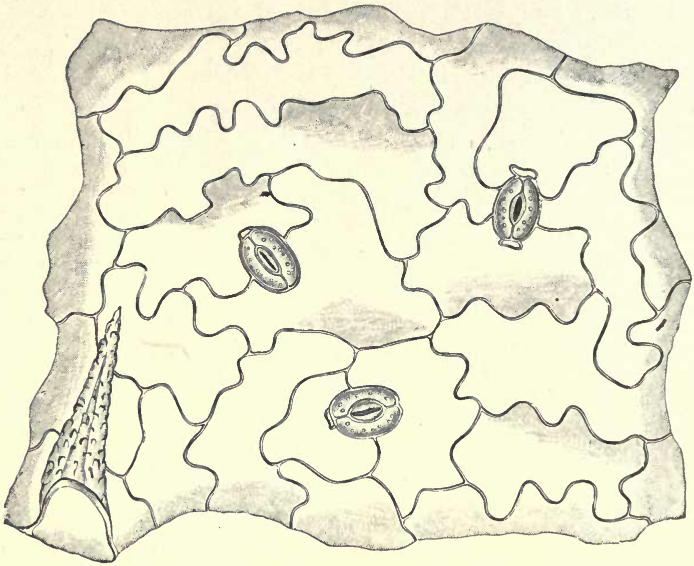

FIG. 535. Hyssop. Lower epidermis of leaf in surface view. (MOELLER.)

slightly wavy (Fig. 534), those of the under side sharply sinuous (Fig. 535). Two adjacent cells, one at each pole, surround each stoma.

Mesophyl crystals are absent.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Planchon et Collin (34); Vogl (44).

BAY-LEAF.

Numerous varieties of the laurel (*Laurus nobilis* L., order *Lauraceæ*) are cultivated in Mediterranean countries. The leaves and fruit serve as spices; the fruit also yields a medicinal aromatic fat.

The leaves (Fig. 536) are short-petioled, lanceolate, at the margin faintly undulate, leathery, smooth, lustrous above, dull and of a lighter color beneath. From the prominent midrib branch off 6 to 8 veins, forming loops near the margin.

HISTOLOGY.

The *Epidermis* (Fig. 538) on both sides bears a thick cuticle. The cells have thick, sinuous, porous walls. Stomata are numerous on the lower epidermis, but do not occur on the upper. They are mostly sunken below the surface, and are surrounded by 4 to 5 cells.

Mesophyl. In cross section (Fig. 537) the oil cells of the mesophyl are conspicuous. These are globular (30–40 μ), and often contain a drop of essential oil. Characteristic also are the collenchyma cells accompanying the bundles, which, like columns, hold the two epidermal layers apart.

FIG. 536. Bay-leaf (*Laurus nobilis*). Natural size. (MOELLER.)

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Moeller (31, 32); Planchon et Collin (34); Vogl (44, 45).

TARRAGON.

This herb (*Artemisia Dracunculus* L., order *Compositæ*), a native of Asia, is much grown in England and on the Continent. It is used fresh as a pot herb and for making tarragon vinegar.

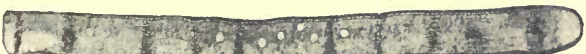

FIG. 537. Bay-leaf. Cross section, slightly magnified. (MOELLER.)

The leaves (Fig. 539) are mostly linear lanceolate, entire, not petioled, thick, smooth, with indistinct venation.

HISTOLOGY.

Epidermis (Fig. 540). Both surfaces have the same structure. The young leaves bear short-stalked multicellular glands; the mature leaves

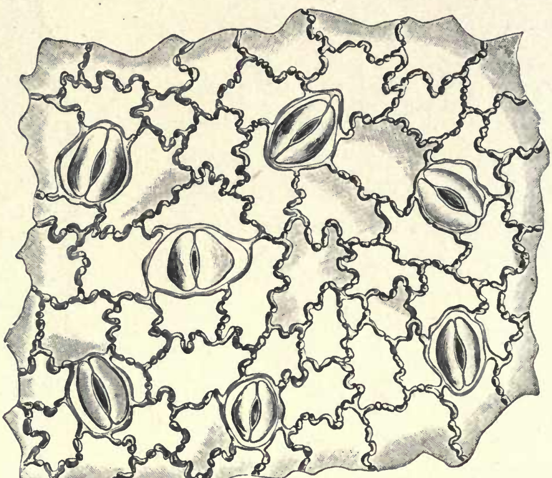

FIG. 538. Bay-leaf. Lower epidermis in surface view. (MOELLER.)

FIG. 539. Tarragon (*Artemisia Dracunculus*). Leaf, natural size. (MOELLER.)

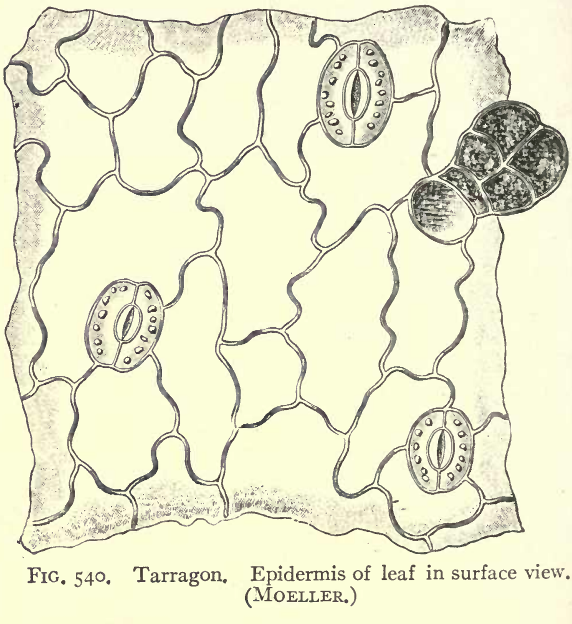

FIG. 540. Tarragon. Epidermis of leaf in surface view. (MOELLER.)

are smooth. The cells are isodiametric with sinuous walls, or elongated with straight walls. Three or more adjacent cells surround each stoma.

Mesophyl crystals are absent.

Other species of *Artemisia* are downy-hairy. Each hair is T-shaped, bearing on a short, jointed stalk a long transversely arranged end cell.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Koch (22); Moeller (30, 31); Planchon et Collin (34); Tschirch (39); Vogl (44).
MEYER, AD.: Off. Blätter u. Kräuter. Halle, 1882.

WORMWOOD.

The European wormwood (*Artemisia vulgaris* L., order *Compositæ*) has pinnately-cleft leaves with irregular, deeply lobed, dentate divisions (Fig. 541). They are dark green above, white or gray, woolly-hairy

FIG. 541. Wormwood (*Artemisia vulgaris*). Leaf, natural size. (MOELLER.)

beneath. In the region of the flowers the leaves are entire. The divisions are lanceolate, prickle-pointed, sparingly veined.

HISTOLOGY.

The *Epidermis* (Fig. 542) on both sides consists of cells with wavy

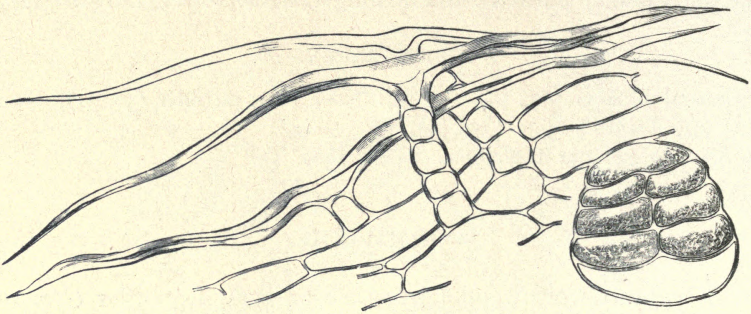

FIG. 542. Wormwood. Epidermis of leaf with hairs. (MOELLER.)

FIG. 543. Sorrel (*Rumex scutatus*). Leaf, natural size. (MOELLER.)

walls, stomata (most abundant beneath), and remarkable T-shaped hairs made up of a 3–4 celled stalk and a long (up to 400 μ) transversely arranged, thin-walled, often collapsed end cell. Glands with several tiers of cells occur sparingly.

BIBLIOGRAPHY.

See Tarragon, p. 619.

SORREL.

French sorrel (*Rumex scutatus* L., order *Polygonaceæ*) is a native of central and southern Europe, where it is also cultivated.

The palmately-veined leaves (Fig. 543) are long-petioled, rounded-cordate or rounded-hastate, with a broad upper lobe and two smaller lobes at the base. They are rather thick, smooth, hoary sea-green, reddish below.

Epidermis (Fig. 544). The cells on both surfaces are large, with thin, wavy walls. Usually three cells adjoin each stoma.

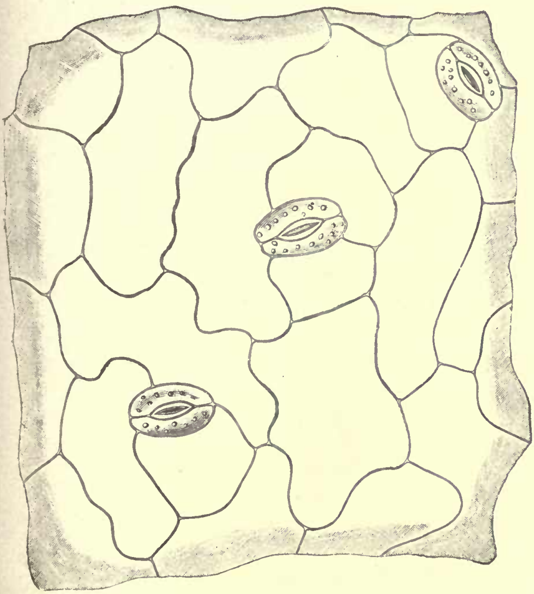

FIG. 544. Sorrel. Epidermis of leaf in surface view. (MOELLER.)

FIG. 545. Sorrel (*Rumex Acetosa*). Leaf, natural size. (MOELLER.)

The Mesophyl contains oxalate rosettes.

The leaves of *Rumex acetosa* L. are long-petioled, saggitate, dark green, smooth, or (beneath) hairy (Fig. 545).

The Epidermis (Fig. 546) is much like that of the preceding species,

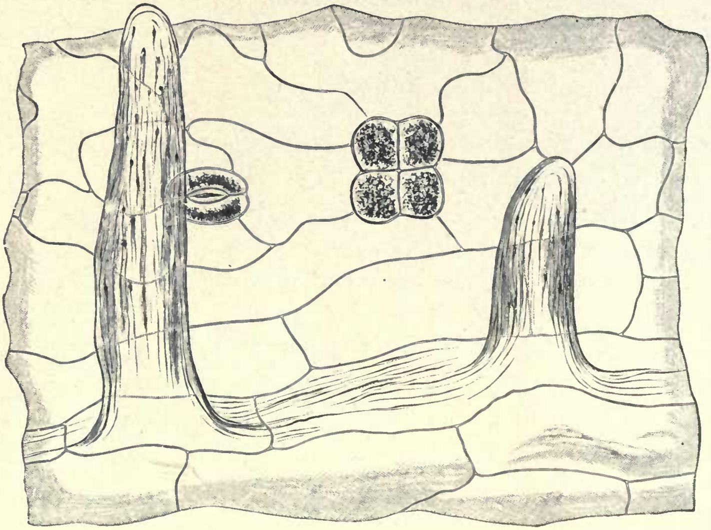

FIG. 546. Sorrel. Epidermis of leaf in surface view. (MOELLER.)

but it bears 4-celled glands with short stalks, also, along the veins, peculiar papillæ with striated cuticle.

Herb Patience (*Rumex patientia* L.), a European pot herb, has large, petioled, oblong or ovate-lanceolate, smooth leaves, with rounded or cordate base and wavy margin.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Planchon et Collin (34); Villiers et Collin (42).

FLOWERS.

The most important products of this class are flower buds (cloves, capers, cassia buds) and stigmas (saffron). Several flowers are used as adulterants of saffron. Cassia buds are described for convenience after cassia bark on p. 591.

The general structure of flowers is discussed on p. 30.

SAFFRON.

Genuine saffron is the dried stigmas of a small bulbous plant (*Crocus sativus* L., order *Iridaceæ*) indigenous to Greece and Asia Minor.[1] In early times the plant was introduced into Italy, from whence it was distributed over central and western Europe as far as England. At present it is grown chiefly in Spain, France, Egypt, Persia, and India. Its culture, although profitable, requires a large outlay of labor in gathering the flowers, which appear during October, and are picked from day to day by hand. The flower consists of a light-colored tube about 10 cm. long and 2–3 cm. broad, which expands at the top and divides into six beautiful violet lobes, corresponding to petals and sepals. A membranous spathe surrounds the tube. The slender yellow style (Fig. 547)

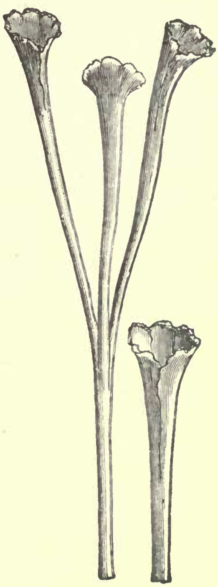

FIG. 547. Saffron (*Crocus sativus*). Style and stigmas. (PLANCHON.)

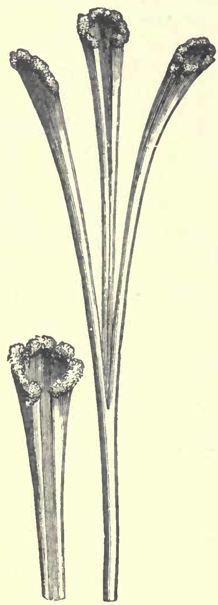

FIG. 548. Spring Crocus (*Crocus vernus*). Style and stigmas. (PLANCHON.)

divides in the crown of the flower into three fleshy, lustrous, revolute, trumpet-shaped, bright orange-red stigmas, 2–3 cm. long, with scolloped edges.

[1] This species should not be confounded with *Crocus vernus* L., numerous varieties of which are cultivated for their spring flowers. The stigmas (Fig. 548) of this species have neither odor nor taste and but little tinctorial power.

In the preparation of commercial saffron the stigmas are separated as completely as possible from the styles, and dried in sieves over fires. The product is characterized by its intense orange-red color, penetrating odor, and peculiar taste.

HISTOLOGY.

After soaking in water, which extracts the larger part of the coloring matter, the form and structure of the stigmas may be studied. The walls of the stigma, although very soft and scarcely more than 0.4 mm. thick, may be held between pieces of pith and sectioned with a razor.

The structure is very simple (Fig. 549). The ground tissue con-

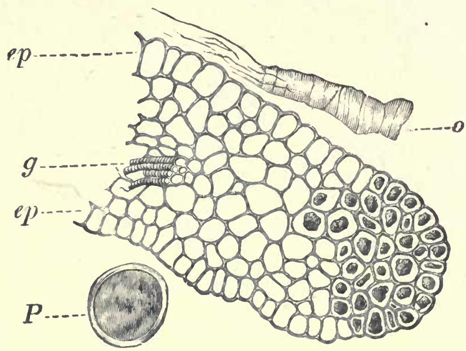

FIG. 549. S ffron. Cross section of stigma at margin. *ep* epidermis; *g* fibro-vascular bundle; *c* separated cuticle; *P* pollen grain. (MOELLER.)

sists of delicate, loosely arranged parenchyma with a few small bundles, between two epidermal layers. Seen in surface view all the cells are elongated up to 200 μ long and 15 μ broad.

Outer Epidermis (Fig. 550, *ep*; Fig. 551). The cuticle is glassy, striated, much stiffer than the cell-walls. The cells are more or less elongated, and each usually bears a short papilla (*p*). These papillæ on the edges of the stigma, where they are especially numerous, are both short and long (up to 400 μ), 20–40 μ broad. On the surface both cells and papillæ are finely granular.

The coloring matter, which is found in all the cells, is fiery red, or in thin sections, yellow. It is insoluble in oil, but dissolves in water and alkalies to a yellow solution, leaving undissolved only a colorless crumbling substance and an occasional oil drop. In glycerine and alcohol it dissolves more slowly. The cell-contents form with concentrated sulphuric acid a blue solution, changing through violet and red into brown. After this treatment fine needles, insoluble in water, separate. Rudolf Müller notes that oxalate crystals are absent, but here and there crystals insoluble in hydrochloric acid are present.

Pollen Grains (Fig. 549, *P*) are often found on the stigmas. They are globular, 120 μ in diameter, and have a thick membrane and colorless granular contents.

DIAGNOSIS.

Saffron is not in such demand as formerly, either as a spice, a drug, or a dyestuff. Although its color is intense, one part imparting a distinct yellow to 200,000 parts of water, the coal-tar colors have largely replaced it as a dye.

Whole Saffron, the form in which the product is usually placed on the market, is readily identified by the macroscopic characters and the

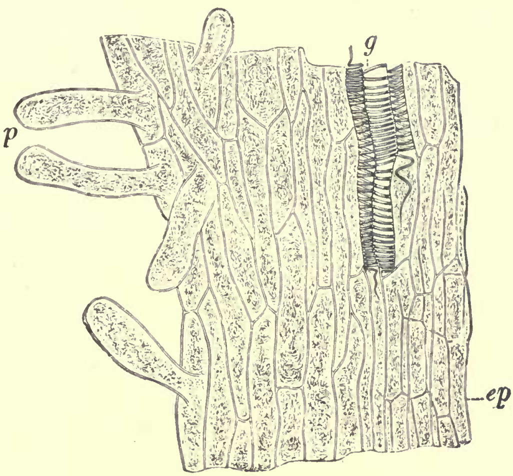

FIG. 550. Saffron. Surface view of stigma. *ep* epidermis; *g* spiral vessel; *p* papillæ. ×300. (MOELLER.)

reactions of the coloring matter, especially its solubility in water, and the blue color imparted by sulphuric acid.

The chief microscopic characters are the elongated parenchyma cells of the epidermis and ground tissue, the former with papillæ (Figs. 550 and 551), and the smooth globular pollen grains (Fig. 549, *P*).

Powdered Saffron is seldom found on the market. The reactions of the coloring matter and the histological characters as given above serve in identification.

Adulterants. Owing to its high cost saffron is often grossly adulterated. The adulterations are chiefly of five classes:

(1) *Saffron Styles*, being yellow, are strikingly different from the orange-red stigmas. If, however, the product is artificially colored, it must be soaked in water, after which the cylindrical styles may be readily distinguished from the trumpet-shaped stigmas. In powder form it is difficult to detect this form of adulteration, owing to the similarity in structure of the two parts. Papillæ such as are present on the edges of the stigma are not found on the style, but failure to find them is no

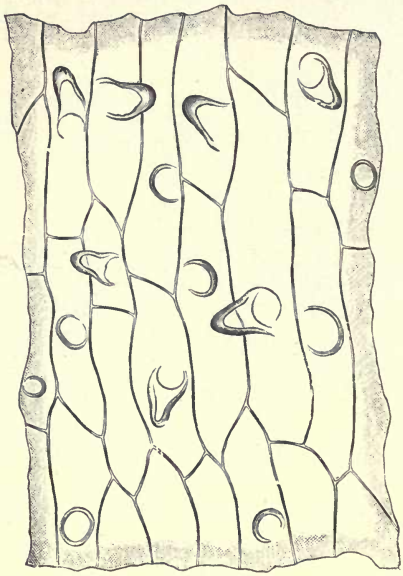

FIG. 551. Saffron. Epidermis of stigma with papillæ. (MOELLER.)

proof of adulteration, since they form but a small portion of the tissues, and are not readily found in the débris. Of greater value in diagnosis are the epidermal cells, which in the style are wavy, and lack papillæ (Vogl). If in oil mounts one finds a considerable amount of homogeneous yellow parenchyma, either styles or extracted stigmas are probably present.

(2) *Parts of Foreign Plants.* The most common adulterants of this class are marigold flowers (p. 627), safflower (p. 629), maize silk (p. 632), red sandalwood (p. 44), and paprika (p. 516). Others occasionally used are: Flowers of *Scolymus hispanicus*, flowers of pomegranate (*Punica granatum* L.); stigmas and stamens of other species of *Crocus*, chopped

grass leaves colored with cochineal and weighted with lime,[1] leaves colored with carmine and weighted with heavy spar,[2] rootlets of chives (*Allium Schœnoprasum* L.),[3] petals of peony (*Pæonia*),[4] petals of poppy (*Papaver Rhœas* L.), garlic rootlets, onion scales, malt sprouts, the etiolated sprouts of vetches, an alga,[5] etc.

(3) *Artificially Colored Saffron.* The exhausted product is sometimes colored with coal-tar dyes. These do not penetrate into the cells, but are deposited on the surface. The material should be examined in water and in oil, and the extracted dye subjected to chemical tests.

(4) *Weighted Saffron* is prepared by soaking in oil, glycerine, sirup, or gelatine, and stirring with mineral substances. Saffron is also said to be soaked in a solution of a barium salt and afterwards in a solution of a sulphate, thus depositing barium sulphate in the cells. These adulterants are detected by determinations of ash and analyses of the ash.

(5) *Coal-tar Dyes* with no vegetable matter whatever are substituted for genuine saffron.

BIBLIOGRAPHY.

See General Bibliography, pp. 671-674: Hanausek, T. F. (10, 16); Linsbauer (48); Macé (26); Meyer (27); Moeller (29, 30, 31, 32); Planchon et Collin (34); Schimper (37); Tschirch u. Oesterle (40); Vogl (43, 45).

CHICOTE: Une novelle falsification du safran. Jour. pharm. chim. 1896, **3**, 116.

HANAUSEK, T. F.: Safranfälschung. Rev. internat. scient. et popul. 1887, **1**, 24.

HANAUSEK, T. F.: Ueber eine neue Safranfälschung. Ztschr. Nahr.-Unters. Hyg. 1888, **2**, 19.

KAISER: Ueber Safranfälschung. Fünfte Versammlung der freien Vereinigung, bayer. Vertr. der angew. Chemie.

KIRKBY: Saffron adulteration. Pharm. Jour. Transact. 337.

MÜLLER, R.: Ueber die vermeintlichen Oxalatkristalle im Safran. Ztschr. allgem. österr. Apoth.-Ver. 1903.

NESTLER: Eigentümliche Kristalle auf den Safrannarben. Ztschr. Unters. Nahr.-Genussm. 1903, **6**, 1034.

RANVEZ: Fälschung von Safran. Ann. Pharm. 1895.

MARIGOLD FLOWERS.

The tasteless and odorless ray-flowers of the marigold (*Calendula officinalis* L., order *Compositæ*), often artificially colored, serve as an adulterant of saffron. The ovary is small, spindle-shaped; the strap-shaped corolla, orange-colored, 4-veined, 3-toothed, upward of 25 mm. long, contracted into a channeled hairy base.

[1] W. Brandes. [2] A. Meyer. [3] Gehe. [4] Jandous. [5] Kanoldt.

HISTOLOGY.

Corolla. The thin blades may be mounted directly in water.

Epidermis (Fig. 552). The cells are elongated, finely striate, arranged end to end in rows. Each contains one or more drops of fatty oil, in

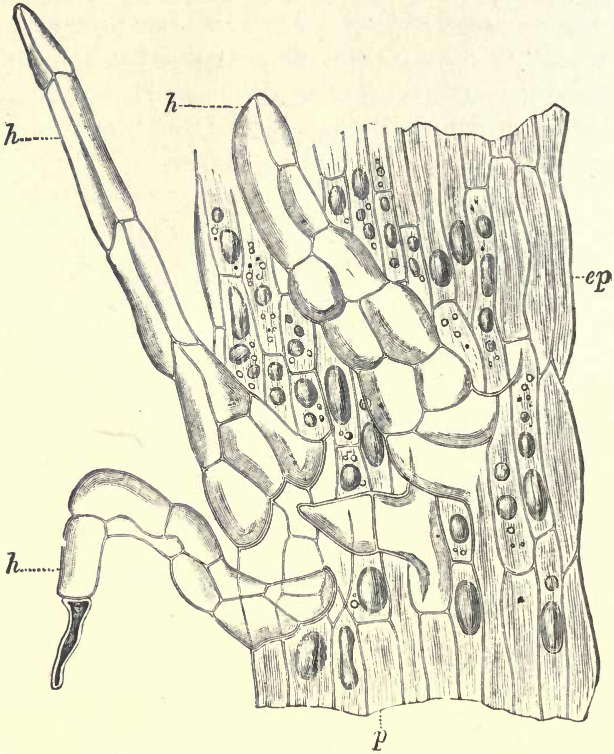

FIG. 552. Marigold (*Calendula officinalis*). Surface view of petal showing *ep* epidermis with *h* hairs and *p* parenchyma with oil globules. ×160. (MOELLER.)

which is dissolved a yellow dye. The numerous hairs (*h*) on the channeled base are over 1 mm. long, and usually consist of two parallel rows of cells, the end cells being often deep yellow and shrunken.

DIAGNOSIS.

Although the dried product somewhat resembles saffron, on soaking in water the difference in microscopic structure is striking. The strap-shaped, 4-veined, 3-toothed corolla narrowed into a channeled hairy base is characteristic. In the ground product the long hairs (Fig. 552, *h*), made up usually of two rows of cells, are readily identified. Water extracts only a trace of color from the uncolored flowers.

SAFFLOWER.

The orange-red flowers of *Carthamus tinctorius* L. (order *Compositæ*), known as safflower, are obtained from India and the Levant. Before marketing they are usually washed to remove the yellow coloring matter, pressed in the hands, and finally dried. The commercial product has little odor or taste.

The red corolla consists of a slender tube over 2 cm. long, ending in five lanceolate lobes (Fig. 553). The yellow anthers are united into a tube 5 mm. long, projecting beyond the corolla, and out of this in turn

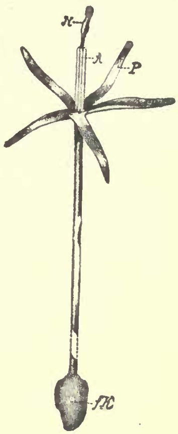

FIG. 553. Safflower (*Carthamus tinctorius*). *P* corolla; *A* anthers; *N* stigma; *fk* ovary. Enlarged. (TSCHIRCH and OESTERLE.)

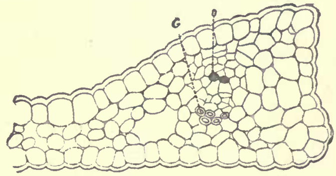

FIG. 554. Safflower. Cross section through the margin of petal. *G* fibro-vascular bundle; *s* resin tube. (TSCHIRCH and OESTERLE.)

projects the club-shaped red stigma. The corolla tube is united below with the pistil. Narrow, white, silky bractlets of the receptacle are often present with the flowers.

HISTOLOGY.

The **Corolla** (Figs. 554 and 555) is much thinner than the stigmas of saffron, and of a deeper color.

Epidermis (*ep*). The cells are elongated, more or less wavy in contour. Papillæ (*p*) similar to those of saffron are limited to the ends of the lobes.

The Middle Layers consist of elongated cells, uncommonly narrow spiral vessels, and, accompanying the latter, tubes containing a dark-brown resin-like material, often in detached cylindrical masses (*s*). In the smaller tubes the interstices between these masses might be mistaken for crystals.

The **Stamens** (Fig. 556) are still more characteristic in structure. They consist of fibrous cells, many of which are beautifully reticulated

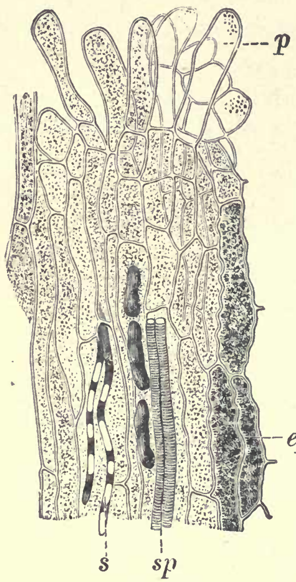

FIG. 555. Safflower. Tissues of petal in surface view. *ep* epidermis with *p* papillæ; *sp* spiral vessels; *s* resin tubes. ×300. (MOELLER.)

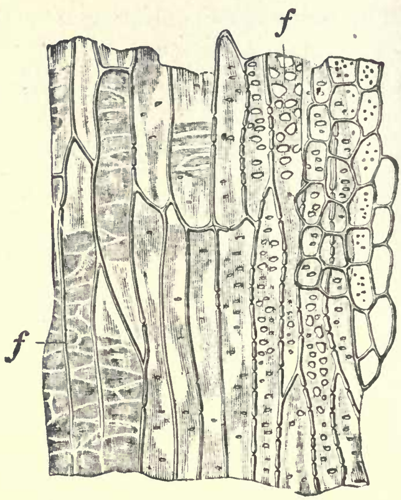

FIG. 556. Safflower. Tissues of stamen in surface view. *f* reticulated and porous fibers. ×300. (MOELLER.)

or else pierced with numerous, uncommonly broad pores. At the place where the filaments join the anthers the cells are isodiametric. Short papillæ occur on the ends of the anthers.

Stigmas (Fig. 557). The numerous thin-walled papillæ are very striking. The *Pollen Grains* (*p*) which are often found on the stigma are triangular, roughened, 40–60 μ, with three excrescences.

The Bracts (Fig. 558) are made up of long (up to 500 μ), narrow (20 μ), parenchymatous cells with reticulated end walls.

The coloring matter exists in the cells as a red, homogeneous or indistinctly granular mass, insoluble in both water and oil. Alkalies turn it yellow.

DIAGNOSIS.

Safflower is used in medicine, and occasionally as an adulterant of saffron. Microscopic examination of the soaked material suffices for the identification of the whole flowers. The characters of chief value in the examination of the powder are the wavy-walled epidermal cells (Fig.

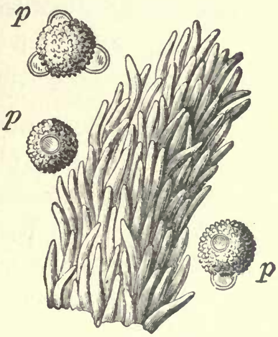

FIG. 557. Safflower. Stigma and *p* pollen grains. ×300. (MOELLER.)

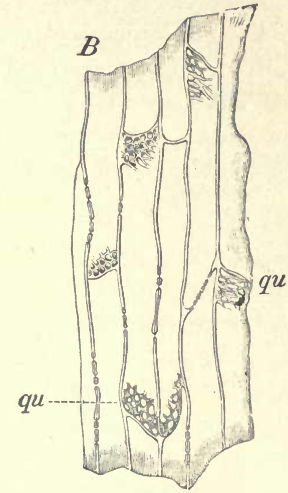

FIG. 558. Safflower. Bract in surface view. ×300. (MOELLER.)

555, *ep*) and the resin tubes (*s*) of the red corolla, the elongated reticulated cells of the filaments and bracts (Fig. 558), the papillæ of the stigmas (Fig. 557), and the roughened triangular pollen grains (Fig. 557, *p*) each with three excrescences. The product imparts little color to water.

CAPE SAFFRON.

The flowers of *Lyperia crocea* Eckl. (order *Scrophulariaceæ*), known in commerce as Cape saffron, resemble true saffron in odor, taste, and dyeing properites, although the two plants belong to widely different families. The calyx is greenish, somewhat inflated, with five linear lobes; the corolla is superior, fugaceous, 25 mm. long, with a long tube, and five spreading, rounded, somewhat revolute lobes. Two short and two long stamens are inserted on the corolla tube. Distributed over the corolla and calyx are large, regularly formed glandular scales, consisting of four cells with a blister-like enlargement of the cuticle. The contents are a colorless substance soluble in alcohol and alkali. The color of the dried flowers is dark brown, becoming lighter on soaking in water (Vogl).

SOUTH AFRICAN SAFFRON.

The flowers of *Tritonia aurea* Pappe (*Crocosma aurea* Pl., *Babiana aurea* Ketsch., order *Iridaceæ*) are used in South Africa as a substitute for saffron. The corolla tube is cylindrical, broadening into a funnel-shaped lobed extremity. The stigma branches are thick, club-shaped at the ends. According to Heine the flowers contain a coloring substance soluble in hot water which is similar to the crocin of saffron.

MAIZE SILK.

The dried thread-like styles and stigmas of *Zea Mays* L., known as maize or corn silk, are used in medicine and chopped into short pieces as an adulterant of saffron. The threads are distinguished from saffron by their flattened, strap-shaped form. Under a low power two parallel bundles, one near each margin, are evident. Multicellular hairs similar to those of marigold, but smaller (0.4–0.8 mm.), occur on the epidermis. The cell contents dissolve in alkali to a brown liquid.

CLOVES.

Cloves are the flower-buds of a small evergreen tree (*Eugenia caryophyllata* Thbg., *Jambosa Caryophyllus* Ndz., *Caryophyllus aromaticus*

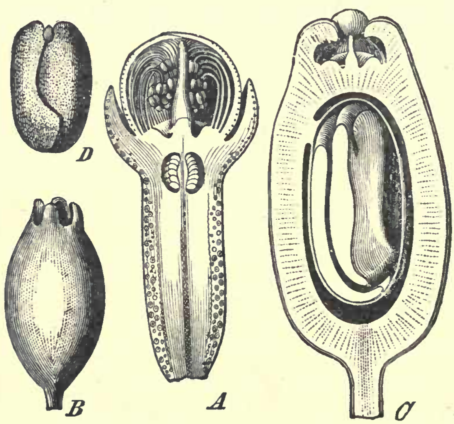

FIG. 559. Cloves (*Eugenia caryophyllata*). *A* flower bud in longitudinal section, ×3 *B* fruit, natural size. *C* fruit in longitudinal section, ×2. *D* embryo, natural size. (LUERSSEN.)

L., order *Myrtaceæ*), a native of the Molucca Islands, but now extensively cultivated in the Philippines, the Sunda Islands, Southern India, Zanzibar and the neighboring islands, the Antilles, and tropical South America. The thrice-forked corymbs, with flowers in groups of three, appear twice a year, in June and December. The buds are either picked by hand or beaten from the tree with reeds and collected on cloths beneath. They are usually dried in the sun, during which process the color changes to brown.

Dried cloves (Fig. 559) have a rounded or somewhat flattened, wrinkled, adherent calyx tube, about 1 cm. long and 3 mm. in diameter, which expands somewhat at the end, and divides into four thick, blunt lobes. In the calyx tube towards the top are two small cavities containing numer-

FIG. 560. Cloves. Cross section through calyx tube. ×25. (MOELLER.)

ous ovules. The four petals alternate with the sepals, and overlap to form a globular head, within which are numerous curved stamens about a single style.

Cloves contain 15–25 per cent of essential oil, which exudes in minute drops on pressing with the finger nail.

HISTOLOGY.

Calyx. A cross section of the calyx tube slightly magnified (Fig. 560) shows an outer ring of oil cavities, an inner ring of bundles, and a slender axis. The structure seen with higher magnification (Fig. 561) is as follows:

1. *Epidermis* (*ep*). The wrinkled epidermis consists of very small cells with uncommonly thick cuticle (15 μ). In surface view (Fig. 563, *A*) the cells are sharply polygonal. Stomata occur here and there.

2. *Parenchyma.* In the outer layers (p_1) the cells are somewhat radially elongated, with thin walls. Proceeding inwards the cells become isodiametric and the walls increase in thickness (p_2). Yellow masses

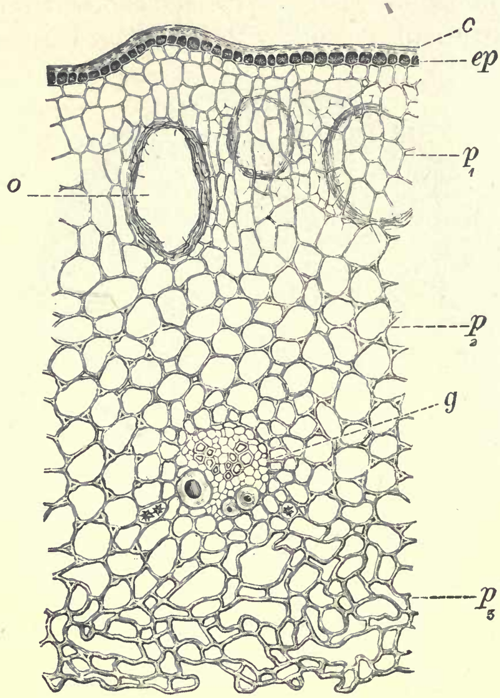

FIG. 561. Cloves. Cross section through calyx tube. *ep* epidermis with *c* cuticle; p_1, p_2, p_3 three forms of parenchyma; *o* oil cavity; *g* fibro-vascular bundle with narrow spiral vessel and thick-walled bast fibers. ×160. (MOELLER.)

becoming blue-black with iron chloride are the visible contents. The oil cavities are in 2 to 3 irregular rows, and, being commonly over 200 μ in diameter, are visible to the naked eye.

3. *The Bundles* (Fig. 561, *g*; Fig. 562) contain very small spiral vessels arranged in radial rows, and a few strikingly broad bast fibers (50 μ). These latter are the only sclerenchyma elements in cloves. Numerous rosettes of calcium oxalate occur in crystal fibers in the bundles and in small groups elsewhere.

4. *Spongy Parenchyma* (p_3). Chains of small parenchyma cells about large intercellular spaces form a ring inside the bundle ring.

The calyx lobes are composed of much the same elements as the tube.

The Corolla is similar in structure to the calyx. The epidermal cells of the outer surface (Fig. 563, *B*) are isodiametric, with wavy walls; those of the inner surface (*C*) isodiametric or elongated, with straight or curved walls. A concentric arrangement of the latter about growing centers is here and there evident. Large oil cavities form a layer near the outer surface, while smaller ones adjoin the inner surface (Fig. 563, *C*). The bundles are narrow (50 μ).

The Stamens and **Styles** contain elements much like those described, but more delicate.

The Pollen Grains (Fig. 564) occur in great numbers in the anthers. They are rounded-triangular, and have distinct pores in the blunt corners.

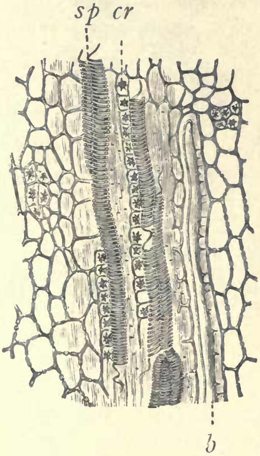

FIG. 562. Cloves. Longitudinal section through fibro-vascular bundle. *sp* spiral vessel; *b* bast fiber with broad cavity; *cr* crystal fibers. (MOELLER.)

DIAGNOSIS.

Whole Cloves should contain the full amount of essential oil and be free from dirt and considerable amounts of stems. When pressed with the finger nail small drops of oil should exude. A deficiency of oil in the cleaned cloves indicates either that the product has lost strength

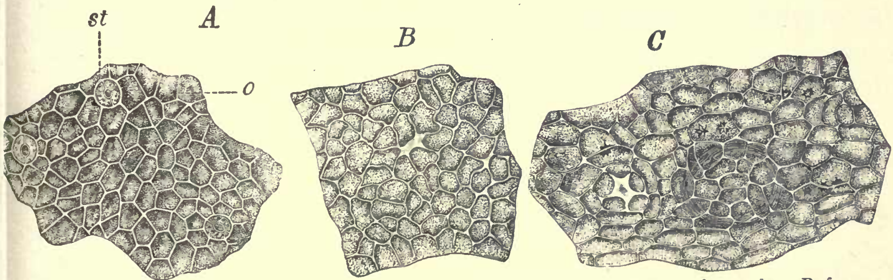

FIG. 563. Cloves. Epidermal tissues from various parts. *A* from calyx tube; *B* from outer surface of petal; *C* from inner surface of petal with underlying oil cavity and crystal rosettes. ×160. (MOELLER.)

by long exposure, or that exhausted cloves, the by-product from the distillation of oil of cloves, have been added. T. F. Hanausek describes artificial cloves made from dough, powdered bark, and clove powder, and Koenig another moulded product made from starch, gum, and oil of cloves. Such products disintegrate on soaking in water.

Ground Cloves. The chief elements are the blunt triangular pollen grains (Fig. 564), the epidermal layers (Fig. 563), the bundles (Fig. 562) with crystal chamber fibers (*cr*), and the thick-walled bast fibers (*b*). Molisch calls attention to the needle crystals of an eugenol salt often found after treating with alkali. Starch is absent, also stone cells.

FIG. 564. Cloves. Pollen grains, enlarged. (MOELLER.)

The adulterants include clove stems (yellow stone cells, reticulated vessels, small starch grains, cork), cocoanut shells (brown stone cells of curious forms), red sandalwood (wood elements with red color, soluble in alkali), also various starchy and non-starchy products.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Berg (3); Hanausek, T. F. (10, 16); Hassall (19); Hilger (10); Leach (25); Linsbauer (48); Macé (26); Meyer, A. (27); Moeller (29, 30, 31, 32); Planchon et Collin (34); Schimper (37); Tschirch u. Oesterle (40); Villiers et Collin (42); Vogl (43, 45).

HANAUSEK, T. F.: Künstliche Gewürznelken. Ztschr. Nahr.-Unters. Hyg. 1889, **3**.

KRAEMER: A Chemical and Microscopical Examination of Cloves. Am. J. Phar. 1894, **66**, 479.

CLOVE STEMS.

Clove stems, the pedicels removed from the flower-buds in harvesting, are used for the manufacture of oil of cloves and as an adulterant of ground cloves and allspice. They vary in diameter (1–4 mm.) according as they are stems of the first, second, or third grade, and have a smooth yellow or wrinkled brown surface. The product contains about 5 per cent of essential oil.

HISTOLOGY.

1. *The Epidermis*, like that of the calyx tube, consists of polygonal cells and stomata. Sometimes the epidermis is replaced by small cork cells.

2. *Cortex.* The ground tissue is parenchyma containing a brown substance partly soluble in water and alkali, with the reactions of tannin, small starch grains (3–5 μ), and rosettes and simple crystals of calcium oxalate. Oil cavities occur beneath the epidermis, and yellow stone

cells (Fig. 565, *st*) both there and in the inner layers. The stone cells in the outer layers are small, thickened only on the inner side; those further inward are large (up to 1 mm.), tangentially elongated, uniformly thickened, faintly stratified, pierced by branching pores.

3. *The Bundles* consist of narrow (25 μ) reticulated and scalariform vessels (Fig. 565, *g*) with phloem and bast fibers on both the outer and

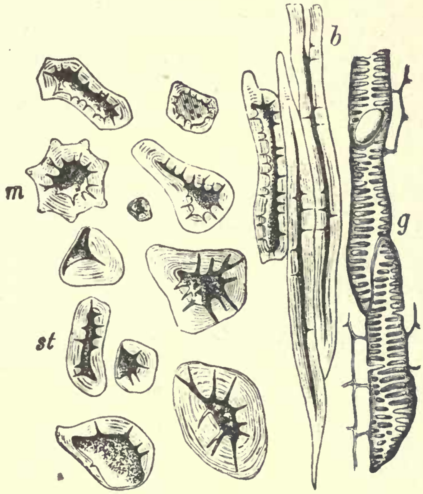

FIG. 565. Clove Stems. *st* stone cells from cortex; *m* star-shaped stone cell from pith; *g* fibro-vascular bundle; *b* bast fibers and stone cells from bast. ×160. (MOELLER.)

inner sides. The bast fibers (*b*) are 700 μ long, 45 μ or less broad, with very narrow lumen and few pores.

4. *Pith.* The parenchyma contains small starch grains and oxalate crystals like those of the cortex. Regularly formed stone cells, often star-shaped (*m*), are also present.

DIAGNOSIS.

The most important elements are the yellow stone cells (Fig. 565, *st*, *m*) and the reticulated and scalariform vessels (*g*). Less noticeable are starch grains, simple crystals, and cork cells. None of these elements occur in the flower-buds.

CLOVE FRUIT.

Mother cloves, the fully ripened fruit of the clove tree, are employed in limited amount in the manufacture of medicines and liquors.

Although the ovary in its early stages of development has two cells and numerous ovules, only one cell and one seed are found in the ripe fruit (Fig. 559, *C*). The latter is but a swollen and ripened clove, 25 mm. long, 8 mm. thick, crowned with the incurved calyx teeth and the remains of the style, but lacking the corolla and stamens.

The seed fills the fruit cavity completely and resembles a small date stone.

HISTOLOGY.

The Pericarp is not materially altered in structure during ripening except that sclerenchyma elements (Fig. 566, *st*) are developed about

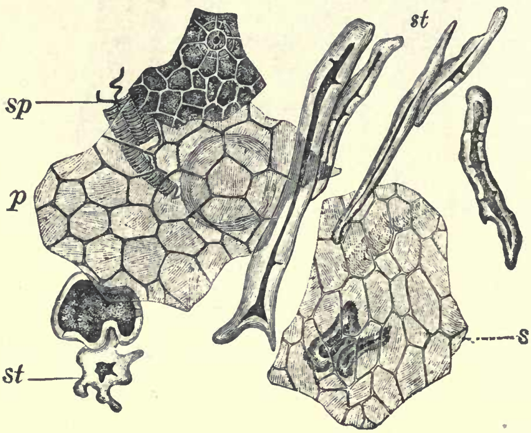

FIG. 566. Clove Fruit. Tissues of pericarp in surface view. *sp* spiral vessels and epicarp; *p* brown parenchyma with underlying oil cavity; *st* stone cells and fibers; *s* endocarp. ×160. (MOELLER.)

the bundles. These vary from bast fibers 800 μ long to isodiametric stone cells, and display a great variety of curious knotty forms. They are easily prepared for study by crushing a piece of the soaked pericarp on a slide and treating with a drop of alkali.

The Embryo (Fig. 567) consists of two dark red-brown, wrinkled cotyledons on a radicle upward of 1 cm. long. The outer surface of the cotyledons is finely granular.

1. *Epidermis* (*ep*). A layer of small cells (12 μ) makes up the epidermal layer.

2. *Oil Cells* (200 μ or less), containing essential oil and a brown pigment, are distributed in the subepidermal layers of ground parenchyma.

3. *Starch Cells* of large size (45 μ) and rounded form, with thick porous walls and intercellular spaces, resemble in their cell-structure the

cotyledon tissues of some of the leguminous seeds, though the starch grains (*am*) are very different, being pear-shaped or truncated with a small hilum at the broader end and delicate markings. The starch grains are seldom more than 40 μ and quite as seldom less than 10 μ. Notwithstanding the truncated ends, suggesting contact with other grains, compound grains are not evident. Fissures occur in some of the grains.

DIAGNOSIS.

The pear-shaped starch grains (Fig. 567, *am*), knotty bast fibers, and stone cells (Fig. 566, *st*) are highly characteristic, the latter being

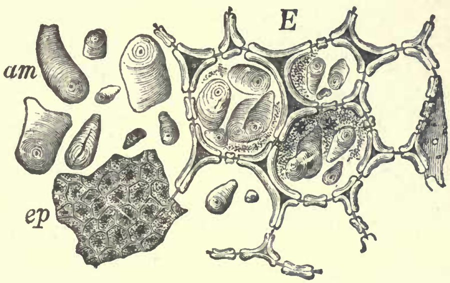

FIG. 567. Clove Fruit. Elements of seed. *ep* epidermis and *E* ground tissue of cotyledon; *am* starch grains. ×300. (MOELLER.)

quite different from the sclerenchyma elements of cloves or clove stems. Banana, yam, sago, and some other tropical starches resemble that of mother cloves; still these are seldom added to spices, and if present there is little fear of confusion, as the stone cells and other tissues of the latter are characteristic.

CAPERS.

Capers are the flower-buds of a shrub (*Capparis spinosa* L., order *Capparidaceæ*), a native of Mediterranean countries, where it is also extensively cultivated. The flowers have four green, thickish, tough sepals, inconspicuous delicate petals, numerous stamens, and a stalked ovary. They are preserved in vinegar and salt, and are much esteemed as a condiment.

HISTOLOGY.

Sepals. The *Epidermis* is characterized by the large cells with striated cuticle (Fig. 568). In the *Mesophyl* are groups of cells containing numerous yellow crystalline needles of a glucoside (rutin) embedded in formless masses. These dissolve in alkali to a yellow liquid.

Petals. The epidermis consists of smaller cells than those of the sepals, and almost circular stomata. On the inner surface are curious

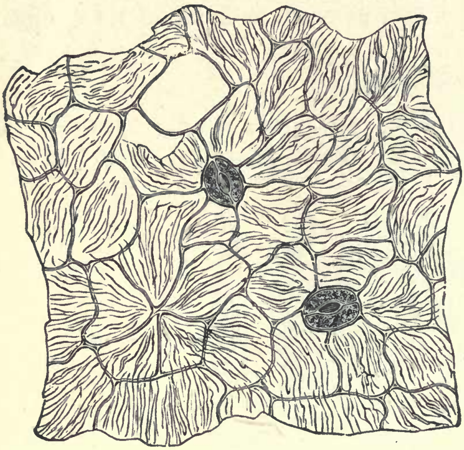

FIG. 568. Capers (*Capparis spinosa*). Epidermis of calyx in surface view. (MOELLER.)

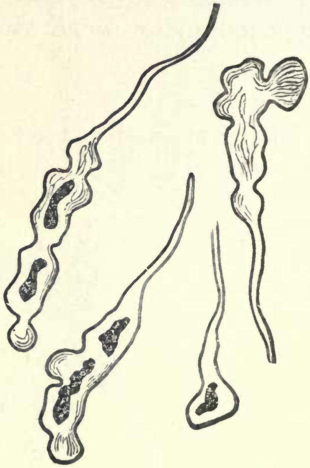

FIG. 569. Capers. Hairs from inner surface of petal. (MOELLER.)

club-shaped hairs (Fig. 569) with irregular constrictions. They are easily removed by scraping.

DIAGNOSIS.

Preserved capers should be small, round, and unexpanded. If old they are soft and discolored. A bright-green color indicates that they have been greened with copper. The following are adulterants:

German Capers, the flower-buds of *Spartium scoparium* L. (*Papilionaceæ*), are prepared in Holland. They have a two-lipped calyx, papilionaceous corolla, ten stamens in a bundle, and a coiled style.

Flower-buds of **Marsh Marigold** (*Caltha palustris* L.—*Ranunculaceæ*) have five yellow sepals, no petals, and 5–10 pistils.

The flower-buds of the garden **Nasturtium** (*Tropæolum majus* L.—*Tropæolaceæ*) have a spurred clayx, five petals with claws, eight stamens and a three-celled ovary. The green fruit is irregularly trefoil-shaped and ribbed. Both buds and fruit are substituted for capers.

Caper Fruits (*Cornichons de câprier*) are elongated, many-seeded berries. They are sometimes mixed with the buds.

PART X.

COMMERCIAL STARCHES.

COMMERCIAL STARCHES.

Although starch is found in enormous quantities in leaves as the first visible product of assimilation (assimilation starch), no great amount accumulates in these organs, as it is continually being converted into sugars or other soluble carbohydrates and translocated to different parts of the plant to build up tissues and form cell-contents. For this reason as well as the small size of the grains and the difficulty of removing the enveloping chlorophyl, the starch of leaves cannot be profitably extracted on a commercial scale.

Transitory Starch, that is, starch temporarily deposited in growing points, barks, and immature fruits and seeds, like the starch of assimilation, has small grains and does not accumulate in considerable quantities.

Reserve Starch. The only form of starch available for the manufacture of the commercial product is the reserve supply stored up in roots, rhizomes, tubers, and stems for the needs of the plants themselves or else in fruits and seeds for the needs of the young offspring. The reserve starch of the cassava plant (*Manihot*) and yam (*Dioscorea*) is stored in the fleshy roots, of Bermuda arrowroot (*Maranta*) and turmeric (*Curcuma*) in the rhizomes or rootstocks, of the potato (*Solanum*) in the tubers, of the sago palm (*Metroxylon*) in the stem, of the banana (*Musa*) in the pericarp or fruit.

It is, however, questionable whether the starch of the banana should be classed under this head, for reasons given on p. 658.

Among seeds, the reserve starch of the legumes (*Leguminosæ*) is stored in the cotyledons, of the cereals (*Graminiæ*) and buckwheats (*Polygonaceæ*) in the endosperm, and of pepper and cubebs (*Piperaceæ*) in the perisperm. By selection, crossing, and cultivation, the size of these natural storehouses as well as their starch content are greatly increased beyond what the needs of the plant demand.

Formation of Reserve Starch. Schimper was the first to demonstrate that reserve starch does not separate directly from the protoplasm of the cell, but is formed through the agency of starch-forming bodies (leucoplasts), physiologically similar to chlorophyl grains (chloroplasts), but differing from them in that they perform their function in the dark. Closely related morphologically to both leucoplasts and chloroplasts are the chromoplasts or color bodies of flowers and fruits.

Leucoplasts are not easily found in most reservoirs of starch, but may be studied in sections of the pseudo-bulb of *Phajus grandiflorus*

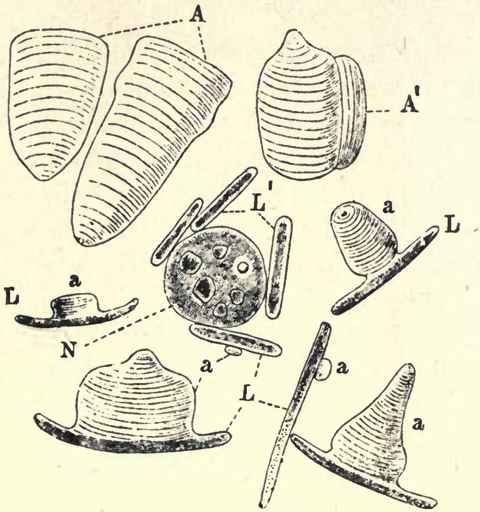

FIG. 570. Starch Grains and Leucoplasts from the pseudo-bulb of *Phajus grandiflorus*. *A* fully developed grains; *a* partially developed grains with *L* adhering leucoplasts; *A'* starch grain with layers deposited on one side; *L'* leucoplasts arranged about the cell nucleus in which are granular bodies. (VOGL.)

(Fig. 570), a well-known greenhouse orchid, also in the rhizome of *Iris Germanica*.

Arthur Meyer explains some interesting relations between the shape of the starch grains and the method of formation. If a single grain is formed within the leucoplast it will grow uniformly on all sides and have a round outline, a central hilum, and concentric rings. If, however, the grain is formed on the sides of the leucoplast it will grow only on the side of attachment, and as a consequence will be elongated and have an excentric hilum and excentric rings. If several grains are formed within a leucoplast, the sides in contact will be flattened; the grains on the surface of the aggregate will have both rounded and flattened surfaces, while those in the inner part, in contact with grains on all sides, will be polygonal.

Chemical Composition. Although starch from different plants has the same percentage composition, the formula being $C_6H_{10}O_5$, or some multiple, it is not one single substance. Three isomeric carbohydrates occurring in varying proportions have been described: (1) granulose or β-amylose, colored blue with iodine; (2) starch cellulose or α-amylose, colored yellow with iodine, and (3) amylodextrine, colored red with iodine. True starch consists of granulose with a small amount of starch cellulose and is colored blue with iodine. The amylodextrine starch of mace, first described by Tschirch, contains, however, only small amounts of these substances, but consists largely of amylodextrine, and consequently is colored red by iodine. Starch cellulose is obtained as delicate skeletons by treating starch grains with saliva.

Starch is converted into a paste by boiling with water. It passes successively into soluble starch, dextrine, and dextrose on boiling with dilute sulphuric or hydrochloric acid. The diastase of malt and the ptyalin of saliva convert it into maltose. By heating at 150–160° C. it is converted into dextrine. It is soluble in caustic soda or potash, and for this reason these alkalies are used to clear starchy mounts for the observation of the tissues.

The Microscopic Characters of starch differ greatly in the different varieties, especially as to the presence or absence of aggregates, the form and size of the grains, their deportment with polarized light, the form, position, distinctness of the hilum or nucleus, the form and distinctness of the rings (Fig. 571).

Aggregates. The grains may be separate or more or less united into aggregates which may consist of any number of individuals from two to several hundred. In the mature organ, the aggregates may be either intact or largely broken up into their component grains.

The Forms of the grains are so numerous even in the same variety as to forbid accurate classification, but the following are the most striking:

1. Globular. The starch of the peanut and some grains of maize.
2. Lenticular. The large grains of wheat, rye, and barley.
3. Ellipsoidal. The starch of legumes.
4. Ovoid or pear-shaped. The starch of potato, canna, Bermuda arrowroot, yam, and banana.
5. Truncated. Most of the grains of cassava, batata, and sago.
6. Polygonal. The starch of maize, rice, oats, and buckwheat.

Globular and lenticular grains ordinarily appear the same, but if, as recommended by Tschirch and Oesterle, the grains are made to move under the cover-glass by drawing the liquid to one side by means of a bit of filter-paper, lenticular grains alternately appear circular or elliptical according as their position. When viewed on edge, lenticular grains are very similar in appearance to ellipsoidal grains. Pear-shaped grains differ greatly, often passing into globular, rod-shaped, sickle-shaped, and various irregular forms.

The term truncated grain as here used includes not only kettledrum forms but forms with two or even three plain surfaces; when, however,

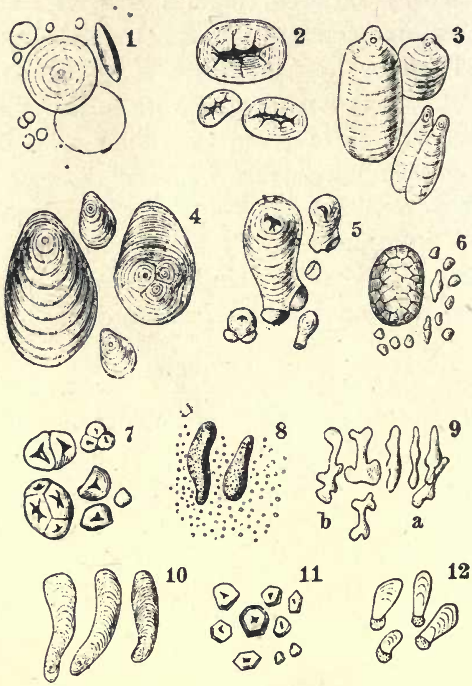

FIG. 571. Forms of Starch Grains. 1 wheat; 2 pea; 3 curcuma; 4 potato; 5 sago; 6 oats; 7 *Colchicum;* 8 cockle; 9*a* *Euphorbia resinifera;* 9*b* *Euphorbia Helioscopia;* 10 banana; 11 maize; 12 *Iris Germanica* (with adhering leucoplasts). ×300. (VOGL.)

several plain surfaces are present, the form is more nearly polygonal. Truncated forms with one and two plain surfaces are separated members of twins and triplets, while polygonal grains are the inner members of larger aggregates.

The Size of starch grains, measured through the longest diameter, ranges from less than 1 μ to over 150 μ. In some varieties the grains are nearly all large (canna), in others all small (rice, buckwheat), in others still, large and small (wheat, rye, and barley). Not only should the maximum and minimum sizes be noted, but also the commonest (not the average) size.

The Hilum or organic center of the grain is conspicuous in some grains (maize, legumes), hardly noticeable in others (wheat, rye, and barley). It may be isodiametric (in most cases a mere point, in maize, however, of considerable size) or else strongly elongated, appearing like a narrow cleft (legumes).

Of great importance is its position, which may be central or nearly so (cereals, cassava), or else excentric, (potato, Bermuda arrowroot, turmeric, canna). The rings of the grain are circular or excentric, according to the location of the hilum about which they are arranged.

Polarized light is of great value in locating the position of the hilum, since the dark crosses which appear on the bright grains with crossed Nicol prisms, intersect at that point (Fig. 572). In grains with central

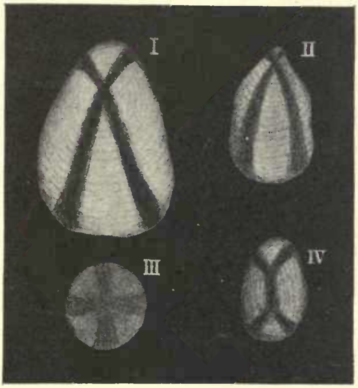

Fig. 572. Starch Grains viewed with Polarized Light. *I* potato. *II* curcuma. *III* wheat; *IV* bean. ×300. (Winton.)

hilum, the dark lines intersect at the center, forming X-shaped crosses. In grains with excentric hilum they often intersect so near one end that they appear to be V-shaped. The crosses in leguminous grains (if they can be so termed) are the shape of two Y's, united thus : Ӽ.

Since the hilum contains more water than other parts of the grain, clefts appear on drying, which in the cereals radiate from the center, in legumes form branches on both sides of the elongated hilum, and in Bermuda arrowroot form double curves resembling the wings of a soaring bird.

The Rings vary greatly in distinctness. They are best seen with oblique illumination, and may be rendered more distinct by treatment with dilute chromic acid, as recommended by Weiss and Wiesner, or by heating the dry starch. They are not evident in wheat, rye, or barley starch except under favorable conditions.

As has been stated, they are circular or excentric according to the location of the hilum. Some authorities regard these rings as due to differences in water content of alternate layers, the hilum containing the highest percentage.

The Crystalline Structure of starch grains is shown by their deportment with polarized light. Viewed with crossed Nicol prisms, the grains form in the dark field luminous objects with more or less distinct crosses. These crosses are very distinct in some varieties (canna, potato, maize), indistinct in others (wheat, rye, barley).

If the selenite plate is added to the polarizing apparatus, a beautiful play of colors is obtained in many varieties.

Various theories have been advanced as to the crystalline structure of the grains, but at present they are regarded as double refractive sphærocrystals or sphærocrystalloids.

Certain *Enzymes*, particularly those of sprouting grain, act slowly on starch grains, the partially dissolved grains showing very distinct rings and branching grooves resembling the burrows of insects (Fig. 30).

Heating, whether dry as in the manufacture of dextrine and the roasting of seeds for coffee substitutes, or wet as in the baking of bread, causes the grains to swell and assume greatly distorted forms. Notwithstanding this distortion, a considerable number of the grains usually preserve enough of their characteristics to permit of identification (Fig. 31).

Commerical Starch. Wiesner describes twenty distinct starches which are made on a commercial scale, but at least half of these are of only local importance.

Wheat and potato starch are mostly made on the Continent; rice starch in England; curcuma and sago starch in the East Indies; Bermuda arrowroot in the West Indies and other warm regions; cassava starch in Brazil and other tropical countries; canna starch in Australia; and maize starch in the United States.

Process of Manufacture. Starch differs from flour in that it is a product of elutriation rather than of milling, and consists almost entirely of one chemical substance, whereas flour contains proteids, fat, cellular matter and ash constituents as well as starch.

The processes employed for making different kinds of starch and in different factories for making the same kind of starch differ in details, but are in general principle the same. The starchy material is reduced to a pulp or powder, with or without previous soaking in water, and the starch washed out from the tissues on sieves. After settling the supernatant liquid is poured off and the residue is further purified by washing, and is finally dried.

In making wheat starch either the whole grain is subjected to a fermentation process, thus forming acetic, lactic and other organic acids in which the gluten is soluble, or else wheat flour is made into a dough and the starch is washed away from the gluten on sieves.

Agitation with dilute alkali is often employed in purifying starch, the nitrogenous substances and some other impurities being soluble in alkaline solutions. Thorough washing of the starch after this treatment is essential, otherwise the finished product is liable to have a slight alkaline reaction which unfits it for certain uses.

Uses. Starch is used in preparing various articles of food, especially puddings and confectionery, also as an ingredient of baking-powders. Enormous quantities are used in the manufacture of glucose and alcoholic liquors. It is a common adulterant of wheat flour, chocolate, cocoa, spices, jellies, and other foods.

Starch is also employed in medicine, as a cosmetic, and still more extensively for laundry purposes and in the arts. Starch paste is a product of no little commercial importance.

Microscopic Examination. The technique of preparing starch for examination is exceedingly simple, and consists merely in mounting in a drop of water or other medium, taking care not to use too much of the material. Oblique illumination aids in making the rings distinct. The shape and size of the grains, the form and position of the hilum and rings, and the presence or absence of aggregates should all be carefully noted. The micropolariscope is of no little assistance not only in locating the hilum, but in differentiating strongly and feebly active starches.

Moeller's Analytical Key to Commercial Starches.

A. All or most of the grains rounded, not from aggregates.
  (*a*) Large grains, rounded, with central hilum; small grains globular or angular.
    1. Large grains, mostly 28–40 μ ....Wheat.
  (*b*) Large grains of various shapes (never lenticular), with excentric hilum.
    * Many grains over 70 μ long.

2. Grains under 100 μ, mostly oyster-shell shaped; hilum in the narrow, pointed end; here and there aggregates and grains with two hilums.. Potato.
3. Many grains over 100 μ, broadly elliptical with a blunt point; hilum in the pointed end.................................... Canna.

** Few grains over 70 μ, much elongated.

+ Many grains over 50 μ; rings distinct.

4. Grains with pointed end, uniform in size (50–60 μ), flattened (seen on edge narrow); hilum in pointed end.............. Curcuma.
5. Grains not pointed; hilum in the narrow but rounded end...... Yam.
6. Grains not pointed; hilum in broad, seldom in narrow end.. Banana.

+ + Grains always under 50 μ, ovate or pear-shaped, not flattened or only slightly.

7. Grains nearly uniform in size (40 μ); hilum central or in the broad end, often with cleft................................ Maranta.
8. Large grains 25–40 μ, club-shaped; hilum in narrow rounded end; clefts absent................................ Erythronium.

+ + + Grains under 30 μ, mostly pear-shaped, seldom in aggregates; hilum and rings indistinct or lacking.

9. Similar to sago, but grains smaller and without rings. Horse-chestnut.
10. Many rounded angular grains........................... Chestnut.

B. Grains polygonal or rounded, with one or more facets (mostly from aggregates).

(*a*) Grains mostly polygonal; hilum central.

11. Grains very small (mostly 6 μ), sharply angular.............. Rice.
12. Large grains (often 20 μ), polygonal or rounded; hilum with clefts. Maize.

(*b*) Grains mostly kettle-drum-shaped (from twins) or with two facets (from aggregates of three).

* Aggregates of one large and two or more small grains.

13. Large grains, often with two separated (not adjacent) facets; hilum excentric.. Sago.

** Aggregates of equal-sized grains.

14. Grains kettle-drum-shaped, seldom over 20 μ; hilum central; rings indistinct.. Cassava.
15. Grains sugar-loaf-shaped, often up to 50 μ; hilum excentric; rings distinct.................................... Sweet potato.

BIBLIOGRAPHY.

See General Bibliography, pp. 671–674: Bell (1); Berg (3); Blyth (5); Greenish (14); Hassall (19); Macé (26); Moeller (29); Tschirch (12); Tschirch u. Oesterle (40); Villiers et Collin (42, 45); Weisner (49); Witmack (10).

v. Höhnel: Die Stärke und die Mahlproducte. Kassel u. Berlin, 1882.

MAIZE STARCH.

By far the larger part of the starch used in the United States is made from maize or Indian corn (*Zea Mays*). Maize starch is also coming into use in Europe.

In manufacturing this product either the whole grain is ground with water and the milky liquid separated from the cellular matter on sieves or the germs and bran are first separated mechanically, and only the starchy endosperm is treated with water to remove the starch. The starch is allowed to settle from the milky liquid and is washed several times by decantation. In some factories it is agitated with very dilute caustic soda, sulphurous acid or other chemicals, to remove nitrogenous constituents, traces of fat and other impurities.

Commercial starch, glucose, dextrines and other starch products are frequently made in the same factory, the process of separation of the starch from the grain being the same whatever the final product.

Maize starch as found on the market is either in coarse granules or a fine powder. The so-called "cornstarch" used in making confectionery and deserts is purified maize starch in powder form.

Adulteration with potato, cassava, and other starches is occasionally practiced.

Microscopic Characters (Fig. 573). Maize starch is the only commercial variety with polygonal grains over 15 μ in diameter. Sorghum starch

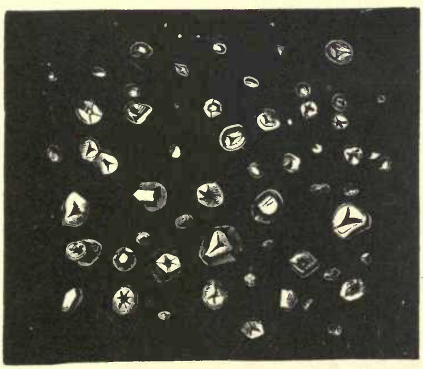

FIG. 573. Maize Starch. ×300. (MOELLER.)

is hardly distinguishable from maize starch, but is not as yet prepared on a commercial scale.

Aggregates. Several polygonal or irregularly rounded grains are often united, but round or oval aggregates, such as are characteristic of rice and oat starch, are not present.

Forms. The grains from the horny endosperm are sharply polygonal and stand out in bold relief. In the floury part of the kernel the grains are irregularly globular.

Size. Both forms of grains range up to 30 μ in diameter, most of them being over 15 μ. Small grains occur in limited numbers.

The Hilum is central and usually very distinct. Radiating clefts are present in many of the grains.

Rings are not evident.

Polarization Crosses. The grains are very brilliant with distinct crosses, but display no marked play of colors with the selenite plate.

RICE STARCH.

Rice starch is the most important starch in England, where it is made in large quantities from Indian paddy. It is also manufactured on the Continent, but not to such an extent as wheat and potato starch.

Although rice (*Oryza sativa*) contains a larger percentage of starch than any of the other common cereals, this starch, like that of the horny endosperm of maize, cannot be separated mechanically until the proteid matter is removed. This is accomplished commonly by soaking with very diulte alkali both before and after grinding, less often by treatment with sodium carbonate, hydrochloric acid or other chemicals, or by fermentation.

The commercial product is of a pure white or yellowish color, according to its purity, and is either in lumps or in powder form. It is used in England chiefly for laundry purposes, as a cosmetic, and in the arts, other kinds being generally preferred for culinary purposes.

Microscopic Characters (Fig. 574). The small polygonal grains distinguish this starch from the other common commercial varieties.

Aggregates, consisting of from two to upwards of a hundred grains, occur in great numbers in the kernel, but are largely disintegrated in the process of manufacture.

Forms. As the grains exist in the kernel chiefly in aggregates the isolated individuals are either polygonal (from the interior of aggregates) or else are rounded on some sides and flattened on others (from the surface of aggregates). Sharply polygonal grains predominate; spindle-shaped forms such as occur in oat starch, or perfectly round grains, are seldom present.

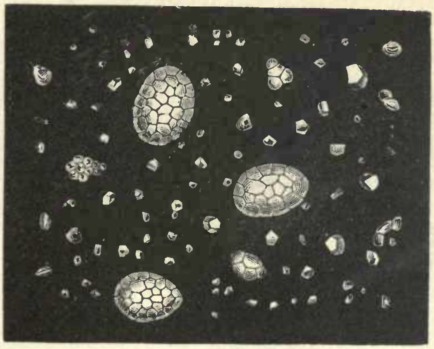

FIG. 574. Rice Starch. ×300. (MOELLER.)

Size. The grains are 2–10 μ in diameter, but seldom reach the latter size.

The Hilum is central but is not always evident.

Rings are not evident.

Polarization Crosses. The grains are brilliant with distinct crosses. No play of color is evident with the selenite plate.

WHEAT STARCH.

On the Continent wheat and potatoes are the chief raw materials for the manufacture of starch. Wheat starch is made usually from common wheat (*Triticum sativum vulgare*), although, according to Wiesner, spelt (*T. sat. spelta*) yields an especially fine product, and English wheat (*T. sat. turgidum*) gives a larger yield than common wheat. Macaroni wheat, because of its horny structure and high content of gluten, is entirely unsuited for starch manufacture, and other varieties and species, although occasionally employed, are of minor importance.

The oldest process of separating the starch is to soak the whole or coarsely ground grain in water until soft, crush between rollers and remove the starch by water. The product obtained by this process has a gray color and contains more or less gluten. A purer product is obtained by subjecting the starchy liquid to a fermentation process, which generates organic acids in which the gluten is soluble. The Martin process consists in making flour into a dough and washing out the starch on sieves with continual kneading. The gluten obtained as a by-product in this process is valuable as a cattle food and for various technical purposes.

The starch appears on the market either as lumps, angular granules, or a fine powder.

Microscopic Characters (Fig. 575). The large lenticular grains characterize this starch.

FIG. 575. Wheat Starch. ×300. (MOELLER.)

Aggregates. The large grains are never united, the small grains only rarely.

Forms. The large grains are lenticular, more or less regularly circular in outline. If mounted in considerable water and drawn across the field by means of a piece of filter-paper they appear alternately circular and elliptical, according as they rest on their sides or their edges. The small grains are usually globular, less often polygonal.

Size. The large grains are commonly 28–40 μ in diameter, but in rare instances reach 50 μ. The small grains are seldom over 6 μ in diameter.

The Hilum is central, appearing usually as a mere dot. Clefts are rare.

The Rings are indistinct.

Polarization Crosses. The large grains are feebly illuminated and show indistinct crosses. No play of colors is evident with the selenite plate.

BUCKWHEAT STARCH.

Common buckwheat (*Fagopyrum esculentum*) is used by certain English manufacturers for making starch, although as yet the product is not of considerable commercial importance.

Microscopic Characters (Fig. 576). Although this starch is similar to rice starch, the rod-shaped aggregates furnish a means of distinction.

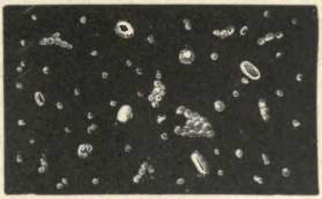

FIG. 576. Buckwheat Starch. ×300. (MOELLER.)

Rod-shaped Aggregates, consisting of several grains but with no evident lines of demarcation, are highly characteristic. They are irregular in shape and have numerous constrictions.

Forms. Polygonal, or rounded polygonal.

Size. The diameters range from less than 2 μ to over 15 μ, but are commonly 6–12 μ.

The Hilum is conspicuous.

Rings are not evident even after treatment with chromic acid.

Polarization Crosses. These are distinct but not striking.

LEGUMINOUS STARCHES.

Starch is occasionally made from beans, peas, and other legumes, although seldom on a commercial scale.

Microscopic Characters (Fig. 577). Leguminous starches are mostly of

FIG. 577. Lentil Starch. ×300. (MOELLER.)

the same type, although differing somewhat in form and size. The ellipsoidal grains with elongated hilum are highly characteristic.

Aggregates are rare.

Forms. Ellipsoidal grains predominate, although reniform, trefoil-shaped and various irregular forms are not uncommon.

Size. In some species the length of the grain reaches 100 μ, but in most of the common species is about 50 μ.

Hilum. The elongated hilum, often with branching clefts, is characteristic. In some grains the hilum and branches being filled with air appear black; in other grains both are indistinct.

Rings distinct.

Polarization Crosses, because of the elongated hilum, are shaped thus: $\overset{\mathsf{Y}}{\lambda}$

CHESTNUT STARCH.

In southern Europe the chestnut (*Castanea sativa* Mill.) is used for the preparation of both flour and starch. Vogl states that chestnut starch is often described as horse-chestnut starch.

Microscopic Characters (Fig. 578). The large grains of curious shapes characterize this starch.

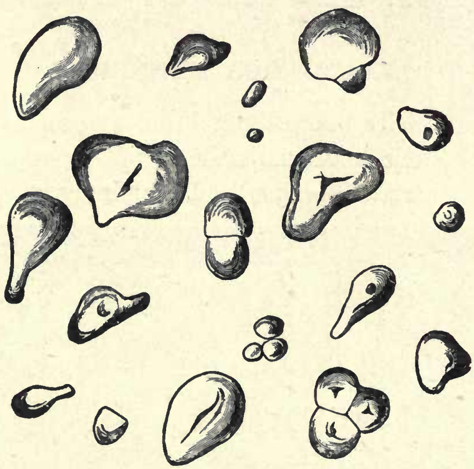

FIG. 578. Chestnut Starch. (MOELLER.)

Aggregates of two or three grains occur here and there, but are not abundant.

Forms. The grains are ellipsoidal, pear-shaped, kidney-shaped, heart-shaped, etc. They are often quite sharp-pointed.

Size. The large grains are 15–30 μ long, the small grains 1–3 μ. Intermediate forms are rare.

Hilum. This is sometimes round, sometimes elongated, forming a cleft much as in leguminous starches.

Rings are indistinct or wanting.

Polarization Crosses are distinct but not striking. With the selenite plate a dull play of colors is evident.

HORSE-CHESTNUT STARCH.

In France a starch is made from the horse-chestnut (*Aesculus Hippocastanum* L., order *Sapindaceæ*), which, although unfit for food because of its bitter taste, is useful in the arts. According to Vogl it is gray-white, whereas chestnut starch is pure white.

Microscopic Characters (Fig. 579). Especially noticeable are the grotesque shapes.

FIG. 579. Horse-chestnut Starch. ×300. (MOELLER.)

Aggregates. Quite often two or more grains are united to form irregularly shaped aggregates. Suppantschitsch (see Wiesner) rightly notes that the individuals of these aggregates are so closely consolidated that they can be distinguished only by the aid of the polariscope.

Forms. Among the grains are numerous pear-shaped reniform, and irregularly swollen forms.

Size. The large grains are mostly 20–30 μ long, but occasionally reach 40 μ. The small grains are often scarcely measurable.

Hilum. This is distinct and is situated at the broader end. A longitudinal cleft passing through the hilum is sometimes present.

Rings are indistinct.

Polarization Crosses are distinct in the large grains. A play of colors is obtained with the selenite plate.

BEAN-TREE STARCH.

The seed of *Castanospermum Australe* Cunn. are used to some extent in New South Wales for the production of starch.

Microscopic Characters. The following description is on Wiesner's authority:

Aggregates. Most of the grains are in aggregates, the number of grains thus united being usually 2–5, less often up to 15.

Forms. Truncated forms from aggregates similar to those of cassava starch predominate. Round grains occur rarely.

Size. The individuals are 2.7–17 μ, but most of them are 5–12 μ.

The Hilum is distinct.

Rings are not evident even after treatment with chromic acid.

BANANA STARCH.

The banana, plantain, and other fruits of the genus *Musa* are remarkable for the large amount of starch stored up in the green pericarp. This is usually regarded as reserve material, but its function is quite different from that of starch stored up in seeds, as it is not utilized by the young plantlet, but like the starch of most green fruits is gradually converted

FIG. 580. Banana Starch. ×300. (MOELLER.)

into sugars during ripening, and in this form is either moved back into the tree, or is lost by fermentation and rotting. Its function is more nearly that of transitory starch.

The green fruit used for starch-making is grown chiefly in tropical regions of America, particularly in Guiana.

According to Wiesner only the flour is made in the regions of production, the starch being separated from the flour in European factories.

The Microscopic Characters (Fig. 580) resemble those of subterranean starches. In addition to the starch grains Vogl finds raphides.

Aggregates. Tschirch and Oesterle call attention to the sickle-shaped forms, consisting of two large grains united end to end.

Forms. Fusiform, cigar-shaped, ovoid, rod-shaped, and other elongated forms are very striking.

Size. Most of the grains are 20–40 μ long; some few however reach 75 μ.

The Hilum is usually situated in the broader end.

The Rings are very distinct.

Polarization Crosses. Distinct crosses are seen with crossed Nicols and a play of colors with the selenite plate.

BREAD-FRUIT STARCH.

The bread-fruit tree (*Artocarpus incisa* L., order *Artocarpeæ*) yields a fruit from which starch has been made in small quantities in South America, Réunion, and other tropical regions.

The Microscopic Characters, according to Wiesner, are as follows:

Aggregates. All of the grains are in aggregates of from 2–20 members.

Forms. Polygonal grains predominate.

Size. 2.5–13 μ, usually about 7 μ.

Hilum and *Rings* are lacking.

Polarization Crosses, although never sharp, may be seen with high power.

POTATO STARCH.

The potato (*Solanum tuberosum* L.) is one of the most valuable sources of commercial starch, although the product is not much used as food, but is chiefly employed in the manufacture of paper and fabrics, for conversion into dextrine and glucose, and for other technical purposes. It is made chiefly on the Continent. In the United States it formerly was an important product, but of late years has been largely replaced by maize starch. The process of manufacture is quite simple. The thoroughly cleaned tubers are ground or grated, the pulp is washed on sieves, and the starch is allowed to settle from the milky liquid.

The commercial product is in lumps, irregular prisms, or a fine powder. The grains are so large as to be visible to the naked eye.

Microscopic Characters (Fig. 581). This starch is recognized by the large, oyster-shell-like grains, each with the hilum in the small end.

FIG. 581. Potato Starch. X 300. (MOELLER.)

Aggregates are rare but curious. They are either true aggregates, usually twins or triplets, or compound grains consisting of two individuals, each with its own hilum and rings, encircled by layers common to both.

Forms. The large grains remind us of oyster-shells. Egg-shaped, pear-shaped, and broadly spindle-shaped forms are common. The small grains are nearly round.

Size. The large grains range up to 100 μ in length, most of them being about 70 μ. The small grains are but a few micromillimeters in diameter.

The Hilum is in the small end, the excentricity being $\frac{1}{3}$–$\frac{1}{6}$.

The Rings are very distinct and are evident without special illumination.

Polarization Crosses are very distinct. With the selenite plate a fine play of colors is obtained.

MARANTA STARCH (WEST INDIA ARROWROOT).

The starch obtained from the rhizome of *Maranta arundinacea* L. (order *Marantaceæ*) and other species of the same genus originally had the undisputed claim to the term "arrowroot," but more recently other tropical starches, particularly those made from roots and rhizomes, have been designated by the same term. Maranta starch is now variously known in commerce as West India, Jamaica, Bermuda, St. Vincent, and Natal arrowroot.

The process of manufacture is essentially the same as is used for making potato starch,—in fact all the varieties of starch made from tubers, rhizomes, and roots are obtained in much the same manner.

West India arrowroot is highly prized for making various dietetic preparations.

Microscopic Characters (Fig. 582). The grains resemble those of potato starch, but are distinguished by their somewhat smaller size, the

FIG. 582. Maranta Starch. ×300. (MOELLER.)

location of the hilum in the broad end and the wing-like fissures through the hilum.

Aggregates are rare or absent

Forms. Ovoid, pear-shaped, and broadly spindle-shaped grains predominate.

Size. The large grains are mostly 30–50 μ long, but occasionally reach 75 μ.

The Hilum is in the broad end and is usually marked by fissures which either form crosses or more commonly extend in two curves resembling the wings of a soaring bird.

The Rings, although distinct, are not so prominent as in potato starch.

The Polarization Crosses and the play of colors with the selenite plate are very striking.

CURCUMA STARCH (EAST INDIA ARROWROOT).

East India, curcuma, or Travencore starch, also known as Tik, Tikor, and Tikur flour, is obtained from the rhizomes of several species of *Curcuma* (order *Zingiberaceæ*), notably, *C. angustifolia* Rxb., *C. Leucorrhiza* Rxb., and *C. rubescens* Rxb. These plants are closely related to turmeric (*C. longa*), and together with ginger belong to the family *Zingiberaceæ.*

Microscopic Characters (Fig. 583). The grains resemble those of ginger,

FIG. 583. Curcuma Starch. ×300. (MOELLER.)

but are more elongated. Like ginger starch they have a curious blunt point in which is located the hilum

Aggregates are rare or absent.

Forms. The grains are much elongated, the length being usually over twice the breadth. The hilum end is distinguished by the curious blunt point.

Size. The grains from *C. Leucorrhiza* sometimes reach 145 μ, but those from the other species seldom exceed 75 μ and are mostly under 60 μ.

The Hilum is a small dot in the point. The excentricity is $\frac{1}{6}$–$\frac{1}{17}$.

Polarization Crosses are distinct, and a beautiful play of colors is obtained with the selenite plate.

CANNA STARCH (QUEENSLAND ARROWROOT).

Queensland, New South Wales, East Indian, or *tous les mois* arrowroot is obtained from the rhizomes of *Canna edulis* Edw., *C. coccinea* Rosc., *C. Indica* L., *C. Achiras* Gill (order *Marantaceæ*), and other species growing not only in Australia and the East Indies but also in Brazil, Venezuela, Réunion, and other tropical regions. It is a glistening white powder with individual grains so large that they are evident to the naked eye.

Microscopic Characters (Fig. 584). This starch, because of the large

FIG. 584. Canna Starch. ×300. (MOELLER.)

size of the grains and the distinctness of the rings, is the most beautiful of all the commercial starches.

Aggregates are wanting or rare.

Forms. The grains are flattened, in outline broadly elliptical or ovate, with a more or less pronounced point or obtuse angle at one end.

Size. Most of the grains are 50 to 70 μ long, but some are over 100 μ, reaching in exceptional cases 135 μ.

The Hilum is in the end with the obtuse angle. Excentricity usually $\frac{1}{5}-\frac{1}{7}$.

Rings are very distinct.

Polarization Crosses are beautiful, as is also the play of colors with the selenite plate.

YAM STARCH (GUIANA ARROWROOT).

Yam starch, or Guiana arrowroot, is made in the tropics from the tuberous roots of *Dioscorea alata* L., *D. sativa* L., *D. aculeata* L., *D. glabra* Roxb., *D. Japonica* Thbg., *D. nummularia* Lam., *D. tomentosa* Koenig (order *Dioscoraceæ*), and other species of this genus.

Microscopic Characters (Fig. 585). This starch resembles curcuma starch, but the grains are not as distinctly pointed. The product is quite variable, owing probably to the different species from which it is derived.

FIG. 585. Yam Starch. ×300. (MOELLER.)

Forms. The grains are flattened in outline, irregularly ovate or reniform. At the broad end they are often truncated; at the narrow or hilum end, rounded or very indistinctly pointed.

Size. Usually the grains are 30–50 μ long, but occasionally reach 80 μ.

The Hilum is in the narrow end. Excentricity $\frac{1}{5}$–$\frac{1}{7}$.

The Rings are evident.

Polarization Crosses are distinct, as is true of most subterranean starches.

CASSAVA STARCH.

The thickened roots of the bitter cassava (*Manihot utilissima* Pohl, order *Euphorbiaceæ*) and the sweet cassava (*M. aipi* Pohl) are used for the production not only of flour, tapioca, and cattle foods, but also of a valuable commercial starch known as cassava, tapioca, or manioca starch, and as Bahia, Rio or Para arrowroot. The starch is made in large quantities in Brazil, and to some extent in other tropical regions, from the root of the bitter cassava, the poisonous prussic acid contained in the fresh root being entirely eliminated by the processes of washing and drying. This product is sold in the United States at a price below that of maize starch, and is used chiefly in the arts. In Florida considerable starch is made from the sweet cassava for use as a size for cotton fabrics.

Microscopic Characters (Fig. 586). This starch is the most important of the commercial varieties with rounded grains truncated on one side. Although in tapioca the grains are more or less distorted, owing to the heating during manufacture, they often retain enough of their characters to permit of identification.

Aggregates, usually of 2–3 grains, less often of 4–8 grains, may be seen in great numbers in sections of the root. In the manufacture of commercial starch these aggregates are mostly broken up into their constituent grains.

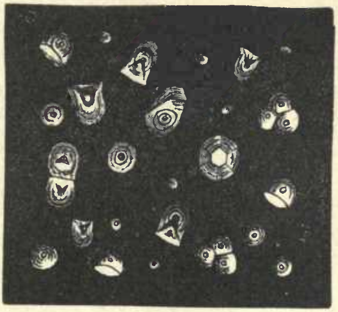

FIG. 586. Cassava Starch. ×300. (MOELLER.)

Forms. The grains are usually kettle-drum- or sugar-loaf-shaped, the flattened surfaces corresponding to the surfaces of contact of twin aggregates. Round grains are rare, those that have that appearance being merely truncated forms resting on the flattened side. Grains with two flattened surfaces (from triplets) are not uncommon, but with more than two surfaces (from aggregates of more than three members) are rare.

Size. The grains occasionally reach 35 μ, but most of the large grains are 20 μ or less. The small grains are less than 15 μ. Grains 50 μ in diameter, such as occur in sweet-potato starch, are never present.

The Hilum is central, and is usually very distinct. Often a triangular enlargement of the hilum extends to the flattened surface. Clefts radiating from the hilum are sometimes present.

Rings are indistinct.

Polarization Crosses are very striking.

SWEET-POTATO STARCH (BRAZILIAN ARROWROOT).

Although the sweet-potato plant (*Batatas edulis* Chois., *Ipomœa Batatas* Lam., order *Convolvulaceæ*) is a native of India, it is grown chiefly in South America, Central America, and the Southern States of the United States. The tuberous roots contain reserve material in the form of both starch and sugar. Wiesner states that sweet potatoes grown in the tropics contain 10 per cent of sugar and only 9 per cent of starch, whereas those grown in subtropical countries contain only 3–4 per cent of sugar and as high as 15 per cent of starch. From these figures it is evident that the roots from the cooler regions are best adapted for the manufacture of starch.

The commercial product is known as Brazilian arrowroot, or sweet-potato starch.

Microscopic Characters (Fig. 587). This starch resembles that of tapioca, but the grains are larger and have an excentric hilum.

FIG. 587. Sweet-potato Starch. $\times 300$. (MOELLER.)

The Aggregates consist mostly of twins and triplets, although some contain as high as six individuals. In the commercial product the grains are mostly detached.

Forms. The grains have one or two, less often more, flat or slightly concave surfaces. Bell-shaped forms are particularly abundant.

Size. Most of the larger grains are 25–35 μ in diameter; some, however, reach 55 μ. The small grains are chiefly 5–15 μ.

The Hilum is distinct, and is frequently marked by radiating fissures. The excentricity is usually about $\frac{1}{2}$, but sometimes reaches $\frac{1}{5}$.

Rings are indistinct.

Polarization Crosses. These are striking.

ARUM STARCH (PORTLAND ARROWROOT).

Portland arrowroot and some other varieties of commercial starch of local importance are obtained from the corms of various species of *Arum* (order *Araceæ*), of which *A. esculentum* L., *A. Italicum* Lam., and *A. maculatum* L. are the most important.

Microscopic Characters. *Aggregates* occur in the root, but not in considerable numbers in the commercial product.

Forms. The grains are either polygonal or rounded, with one or more facets.

Size. The maximum diameter is 20 μ, the usual diameter less than 15 μ.

The Hilum is central.

Rings are indistinct.

TACCA STARCH (TAHITI ARROWROOT).

This starch, also known as Williams' arrowroot and *fécule de pia,* is made from the roots of *Tacca pinnatifida* Forst., order *Taccaceæ,* a plant grown not only in Tahiti and neighboring islands, but also in Brazil and India.

Microscopic Characters. According to the description of Tschirch and Oesterle the grains are irregularly egg-shaped, with excentric hilum and distinct rings. The large grains are usually 38–50 μ, but vary up to 85 μ. Wiesner states that the largest grains measure 45 μ, and further notes the presence of polygonal grains of somewhat smaller size from aggregates.

Further observations on authentic material are desirable.

SAGO.

Reserve starch is deposited in large amounts during certain periods of growth in the pith of palms and cycads for use during the fruiting season. In India and the East Indies this starch is extracted in enormous quantities from two palms, *Metroxylon Rumphii* Mart. (*Sagus Rumphii* Willd.) and *M. læve* Mart. (*S. lævis* Rumph.), and in considerable quantities from *M. Sagus, M. Koenigii* Rumph., *Arenga saccharifera* Labill, *Borassus flabelliformis* L., *Caryota urens* L., and other allied species.

Sago is also obtained from *Cycas revoluta* L., and other cycads.

The processes of manufacture of sago starch and pearl sago are much the same as are employed in making starch and tapioca from the cassava root. The pith of the tree, separated from the hard outer layers, is reduced to a pulp, and the starch is washed out on sieves. Soluble impurities and matters in suspension are removed by repeated agitation with water and decantation. The moist starch after drying yields sago flour or sago arrowroot.

In the preparation of pearl sago the moist starch is converted into coarse granules by rubbing through sieves, and these granules are dried, rounded by agitation in bags, and finally heated until the starch grains are partially destroyed. The granules are from 1–4 mm. in diameter, horny in texture, and semitransparent.

Microscopic Characters (Fig. 588). The starch is highly characteristic

FIG. 588. Sago. ×300. (MOELLER.)

in microscopic appearance, even in pearl sago and other partially cooked products.

Aggregates of one large irregular grain, with one or two (rarely three or more) small grains, make up the larger part of the original material, but in the process of manufacture many of these aggregates are broken up.

Forms. The large detached grains from the aggregates are irregular in shape, and show the surfaces of contact. When two of these surfaces are present they are usually at different corners of the grain, and not adjacent, as in the starch grains of tapioca. A few of the large grains, and many of the small grains, do not bear evidences of being members of aggregates.

The small grains from aggregates are plano-convex.

Size. The large grains are mostly 30–50 μ long, but sometimes range up to 80 μ; the small grains are 20 μ or less long.

The Hilum has usually an excentricity of $\frac{1}{3}$–$\frac{1}{5}$, and is frequently crossed by fissures.

The Rings and *Polarization Crosses* are distinct.

In pearl sago and other cooked products the above characters are more or less indistinct.

As formerly prepared sago flour usually contained considerable amounts of tissues and cell-contents, especially stone cells, hairs, raphides, and

FIG. 589. Erythronium Starch. (MOELLER.)

crystal clusters, but at present these impurities are largely removed by the improved processes of manufacture.

MISCELLANEOUS STARCHES.

The starches described in the foregoing sections are those best known in commerce. Others of local importance are obtained from the plants given in the following table:

Order and Species.	Part Used.	Locality.
Amaryllideæ:		
Alstrœmeria pallida Grah.	Bulb	Chili
Bomarea sp.	"	"
Pancratium maritimum L.	"	Italy
Anacardiaceæ:		
Mangifera Indica L. (mango)	Seed	West Indies
Araceæ:		
Amorphophallus sp.	Corm	" "
Colocasia antiquorum Schott	"	Martinique
Dracontium sp.	"	West Indies
Typhonium sp.	"	" "
Araucariaceæ:		
Araucaria sp		Brazil

Order and Species.	Part Used.	Locality.
Cucurbitaceæ :		
Bryonia epigæa Rottl....................	Root	East Indies
Sechium edule Sw......................	"	West Indies
Sicyos angulatus D.C....................	"	Réunion
Gramineæ :		
Eleusine Coracana Gaertn.................	Seed	West Indies
Hypoxideæ :		
Hypoxis aurea Lam......................	Bulb	East Indies
Leguminosæ :		
Dolichos bulbosus L.....................	Root	Japan
Parkia biglandulosa.....................	Pod	East Indies
Pueraria Thunbergiana Kunth............	Seed	Japan, China
Liliaceæ :		
Erythronium Dens-canis L................	Bulb	Japan
Fritillaria imperialis L..................	"	France
Gloriosa superba L......................	"	East Indies
Yucca gloriosa L........................	Bulbous root	Central America
Malvaceæ :		
Pachira aquatica Aubl...................	Seed	Guiana
Nymphæaceæ :		
Nelumbium speciosum Willd..............	Root	China

GENERAL BIBLIOGRAPHY.

1. BELL: The Chemistry of Foods. With Microscopic Illustrations. London. Part I, 1881; Part II, 1883.
2. BENECKE: Anleitung zur mikroskopischen Untersuchung der Kraftfuttermittel auf Verfälschungen und Verunreinigungen. Mit 44 in den Text gedruckten Abbildungen. Berlin, 1886.
3. BERG: Anatomischer Atlas zur Pharmazeutischen Waarenkunde in Illustrationen auf fünfzig in Kreidemanier lithographierten Tafeln nebst erläuterndem Texte. Berlin, 1865.
4. BERG UND SCHMIDT: Darstellung und Beschreibung sämtlicher in der Pharmac. Borussica aufgeführten officinellen Gewächse. Leipzig, 1859.
5. BLYTH: Foods: Their Composition and Analysis. A Manual for the Use of Analytic Chemists and Others. With an Introductory Essay on the History of Adulteration. With Numerous Tables and Illustrations. London. 2d Ed. 1882, 5th Ed. 1903.
6. BÖHMER: Die Kraftfuttermittel, ihre Rohstoffe, Herstellung, Zusammensetzung, Verdaulichkeit und Verwendung, mit besonderer Berücksichtigung der Verfälschungen und der mikroskopischen Untersuchung. Berlin, 1903.
7. Entwürfe für den Codex alimentarius Austriacus. Ztschr. Nahr.-Unters. Hyg. 1891 u. ff.
8. COLLIN: Guide pratique pour la détermination des poudres officinales. Paris, 1893.
9. COLLIN ET PERROT: Les résidus industriels de la fabrication des huiles et essences, utilisés par l'agriculture. Paris, 1904.
10. DAMMER: Illustriertes Lexikon der Verfälschungen und Verunreinigungen der Nahrungs- und Genussmittel u.s.w. Unter Mitwirkung von Fachgelehrten und Sachverständigen herausgegeben. Leipzig. I. Band, 1885; II. Band, mit 5 Farbendrucktafeln und 734 in den Text gedruckten Abbildungen, 1887.
    - BÖHMER: Oelkuchen.
    - HANAUSEK, T. F.: Kaffee; Thee; Safran; Pfeffergewürze; Muskatnuss; Zimmt.
    - HILGER: Gewürznelken.
    - MEYER, ARTHUR: Ingwer; Senf; Kardamomen.
    - WEIGMANN: Kakao.
    - WITTMACK: Brot; Mehle; Stärke.

11. FLÜCKIGER: Pharmakognosie des Pflanzenreiches. Berlin, 1876. Zweite Aufl., 1881; Dritte Aufl., 1891.

12. GEISSLER-MOELLER: Real-Encyclopädie der gesammten Pharmacie. Wien, 1. Aufl. 1886–91; 2. Aufl. (Moeller-Thoms), 1904 u. ff.

13. GIRARD ET DUPRÉ: Analyse des matières alimentaires et recherche de leurs falsifications. Paris, 1894.

14. GREENISH: The Microscopical Examination of Foods and Drugs. A Practical Introduction of the Methods Adopted in the Microscopical Examination of Foods and Drugs, in the Entire, Crushed and Powdered States. London, 1903.

15. GREENISH AND COLLIN: An Anatomical Atlas of Vegetable Powders. Designed as an Aid to the Microscopic Analysis of Powdered Foods and Drugs. London, 1904.

16. HANAUSEK, T. F.: Die Nahrungs- und Genussmittel aus dem Pflanzenreiche. Nach den Grundsätzen der wissenschaftlichen Waarenkunde für die Praxis und zum Studium. Mit 100 in den Text eingedruckten meist anatomischen Holzschnitten. Kassel, 1884.

17. HANAUSEK, T. F.: Lehrbuch der technischen Mikroskopie. Mit 256 in den Text Gedruckten Abbildungen. Stuttgart, 1901.

18. HARZ: Landwirthschaftliche Samenkunde. Handbuch für Botaniker, Landwirthe, Gärtner, Droguisten, Hygieniker. Mit 201 in den Text gedruckten Originalholzschnitten. 2 Bänder. Berlin, 1885.

19. HASSALL: Food: Its Adulterations, and the Methods for Their Detection. Illustrated by upwards of 200 Wood Engravings. London, 1876.

20. JELLIFFE: An Introduction to Pharmakognosy. Philadelphia, 1904.

21. KLENKE: Die Verfälschungen der Nahrungsmittel und Getränke, etc. Leipzig, 1858.

22 KOCH: Die mikroskopische Analyse der Drogenpulver. Ein Atlas für Apotheker, Drogisten und Studierende der Pharmazie. Berlin, 1900 u. ff.

23. KÖNIG: Die Untersuchung landwirtschaftlich und gewerblich wichtiger Stoffe. Parktisches Handbuch. Mit 202 Textabbildungen und einer farbigen Tafel. Berlin, 1891. Zweite, neubearbeitete Auflage, mit 248 Textabbildungen und einer farbigen Tafel, 1898.

BÖHMER: Mikroskopische Untersuchung der Hülsenfrüchte, Oelsamen und Unkrautsamen.

24. KRAEMER: A Course in Botany and Pharmacognosy. Philadelphia, 1902.

25. LEACH: Food Inspection and Analysis. For the Use of Public Analysts, Health Officers, Sanitary Chemists and Food Economists. New York, 1904.

26. MACÉ: Les substances alimentaires étudiées au microscope surtout au point de vue de leurs altérations et de leurs falsifications. Avec vingt-quatre planches coloriées dont huit reproduites d'après les études sur le vin de M. L. Pasteur et 408 figures dans le texte. Paris, 1891.

27. MEYER, ARTHUR: Wissenschaftliche Drogenkunde. Ein illustriertes Lehrbuch der Pharmakognosie und eine wissenschaftliche Anleitung zur eingehenden botanischen Untersuchung pflanzlicher Drogen für Apotheker. Erster Teil mit 269 Abbildungen. Berlin, 1891. Zweiter Teil (Schluss des Werkes) mit 387 Abbildungen. Berlin, 1892.

28. MEYER, ARTHUR: Die Grundlagen und die Methoden für die mikroskopische Untersuchung von Pflanzenpulvern. Eine Einführung in die wissenschaftlichen Methoden der mikroskopischen Untersuchung von Gewürzen, pflanzlichen Arzneimitteln, Nahrungsmitteln, Futtermitteln, Papieren, Geweben u.s.w. Zum Gebrauche in den Laboratorien der Hochschulen und zum Selbstunterrichte. Für Nahrungsmittelchemiker, Apotheker, Techniker u.s.w. Mit 8 Tafeln und 18 Figuren im Texte. Jena, 1901.

29. MOELLER: Mikroskopie der Nahrungs- und Genussmittel aus dem Pflanzenreiche. Mit 308 vom Verfasser gezeichneten Figuren in Holzschnitt. Berlin, 1886.

30. MOELLER: Lehrbuch der Pharmakognosie. Mit 237 Abbildungen. Wien, 1889.

31. MOELLER: Pharmakognostischer Atlas. Mikroskopische Darstellung und Beschreibung der in Pulverform gebräuchlichen Drogen. Mit 110 Tafeln in Lichtdruck nach Zeichnungen des Verfassers. Berlin, 1892.

32. MOELLER: Leitfaden zu mikroskopisch-pharmakognostischen Uebungen für Studierende und zum Selbstunterricht. Mit 409, zumeist vom Verfasser gezeichneten Figuren im Texte. Wien, 1901.

33. MOLISCH: Grundriss einer Histochemie der pflanzlichen Genussmittel. Jena, 1892.

34. PLANCHON ET COLLIN: Les drogues simples d'origine vegetale. Paris. T. I. 1895; T. II. 1896.

35. ROSEN: Anatomische Wandtafeln der vegetabilischen Nahrungs- und Genussmittel. Breslau, 1897.

36. RUPP: Die Untersuchung von Nahrungsmitteln, Genussmitteln und Gebrauchsgegenständen. Praktisches Handbuch für Chemiker, Medicinalbeamte, Pharmazeuten, Verwaltungs- und Justizbehörden u.s.w. Mit 115 in den Text gedruckten Abbildungen. Heidelberg, 1894.

37. SCHIMPER: Anleitung zur mikroskopischen Untersuchung der Nahrungs und Genussmittel. Jena. Erste Aufl. mit 79 Holzschnitten, 1886. Zweite umgearbeitete Aufl. mit 134 Abbildungen, 1900.

38. TICHOMIROW: Lehrbuch der Pharmakognosie. Moscow, 1900.

39. TSCHIRCH: Angewandte Pflanzenanatomie. Ein Handbuch zum Studium des anatomischen Baues der in der Pharmacie, den Gewerben, der Landwirthschaft und dem Haushalte benutzten pflanzlichen Rohstoffe. Erster Band. Allgemeiner Theil: Grundriss der Anatomie. Mit 614 in den Text gedruckten Holzschnitten. Wien und Leipzig, 1889.

40. TSCHIRCH U. OESTERLE: Anatomischer Atlas der Pharmakognosie und Nahrungsmittelkunde. Ca. 2000 Originalzeichnungen auf 81 Tafeln mit begleitendem Text. Leipzig, 1900.

41. Vereinbarungen zur einheitlichen Untersuchung und Beurtheilung von Nahrungs- und Genussmitteln sowie Gebrauchsgegenständen für das Deutsche Reich. Berlin, 1897. Heft II, 1899; Heft III, 1902.

42. VILLIERS ET COLLIN: Traité des altérations et falsifications des substances alimentaires. Avec 633 figures dans le texte. Paris, 1900.

43. VOGL: Nahrungs- und Genussmittel aus dem Pflanzenreiche. Anleitung zum richtigen Erkennen und Prüfen der wichtigsten im Handel vorkommenden Nahrungsmittel, Genussmittel und Gewürze mit Hilfe des Mikroskops. Mit 116 feinen Holzschnittbildern. Wien, 1872.

44. VOGL: Arzneikörper aus den drei Naturreichen in pharmakognostischer Hinsicht. Commentar zur österr. Pharmacopoe. Wien. Dritte Aufl. 1880; siebente Aufl. 1892.

45. VOGL: Die wichtigsten vegetabilischen Nahrungs- und Genussmittel mit besonderer Berücksichtigung der mikroskopischen Untersuchung auf ihre Echtheit, ihre Verunreinigungen und Verfälschungen. Mit 271 Holzschnitten. Berlin und Wien, 1889.

46. WIGAND: Lehrbuch der Pharmakognosie. Berlin, 1863; vierte Aufl. 1887.

47. WIESNER: Einleitung in die technische Mikroskopie nebst mikroskopisch-technischen Untersuchungen. Wien, 1867.

48. WIESNER: Die Rohstoffe des Pflanzenreiches. Versuch einer technischen Rohstofflehre des Pflanzenreiches. Leipzig, 1873. Zweite gänzlich umgearbeit. und erweit. Aufl. I. Bd. mit 153 Textfiguren, 1900; II. Bd. mit 297 Textfiguren, 1903.

HANAUSEK, T. F.: Samen und Früchte.

HÖHNEL: Rinden.

KRASSER: Blätter und Kräuter.

LINSBAUER: Blüthen und Blüthentheile.

VOGL: Unterirdische Pflanzentheile.

WIESNER: Stärke.

49. WILEY ET AL.: Foods and Food Adulterants. U. S. Department of Agriculture, Division of Chemistry, Bulletin No. 13, Washington, 1887.

GLOSSARY.

Accompanying Cells. The cells adjoining the guard-cells of a stoma.

Accumbent. Applied to seeds with radicle against the edges of the cotyledons (p. 173).

Achene. A small dry, indehiscent, one-seeded carpel with a leathery pericarp.

Adnate. Grown to another part.

Aerial Stem. A stem formed above ground as distinguished from rhizomes and other subterranean stems (p. 39).

Aggregate. Used of starch grains united to form a body of definite shape.

Aggregate Fruit. A fruit formed by the ripening of a flower with several ovaries (p. 33; Fig. 256).

Aleurone Cells, or **Aleurone Layer.** Strictly, cells of the perisperm or embryo, containing aleurone grains and fat, but no starch. The so-called aleurone or gluten cells of the cereals contain fat in an amorphous proteid network, but neither aleurone grains nor gluten (p. 62; Figs. 33 and 38).

Aleurone Grains. Proteid bodies of various forms occurring chiefly in seeds (p. 24; Fig. 7).

Alkaloids. A group of nitrogenous substances with marked toxic or stimulating properties (p. 25).

Amphitropous. See *Hemitropous.*

Amylodextrin. A carbohydrate intermediate between dextrin and starch.

Amylodextrin Starch (p. 534).

Anastomosis. The joining of veins by cross-veins, forming a network.

Anatropous. Inverted; applied to ovules and seeds with foramen or micropyle at the hilum, connected by the raphe with the chalaza at the opposite end (Fig. 19).

Angiosperms, or **Angiospermous Plants.** Phenogams with ovules inclosed in an ovary.

Annular Vessels. Vessels with thickened rings (Fig. 25).

Anther. The body at the extremity of the stamen, containing the pollen grains (p. 31).

Apex. The end farthest from the point of attachment or base of an organ.

Arillode. An appendage of a seed growing out of the micropyle.

Arillus, or **Seed Mantle.** An appendage of a seed growing out of the hilum (Fig. 448).

Ascus, pl. **Asci.** A sac producing spores within (p. 420; Fig. 325).

Assimilation. See *Photosynthesis.*

Assimilation Starch. The starch formed in chlorophyl grains.

Astroscelereid. Star-shaped stone-cell.

Awn. A bristle borne on the glume or palet of a grass.

Axil. The upper angle between a leaf and a stem.

Bark. All the tissues of perennial stems outside of the cambium layer (p. 40; Fig. 24).

Basidium, pl. **Basidia.** A sac producing spores on its surface (p. 420).

Bast. See *Phloem.*

Bast Fibers. Greatly elongated, pointed cells with thick porous walls (p. 21; Fig. 5).

Beaker Cells. Cells with thickened radial and inner walls (p. 173; Fig. 144).

Bracts. The small leaves or scales subtending a flower or its pedicel.

Bulb. A leaf bud (usually subterranean) surrounded by thickened scales.

Bundle Sheath. A group of bast fibers surrounding or adjoining a bundle (Figs. 231 and 232).

Calyx. The outer floral envelope, consisting of sepals.

Cambiform Cells. Elongated elements of the phloem with non-porous cross partitions (Fig. 6).

Cambium Layer. The active tissue of exogenous stems and roots, forming phloem on the outside and xylem on the inside (p. 39).

Campylotropous. Applied to ovules and seeds with the hilum and chalaza at the point of attachment, but with the body so curved as to bring the foramen or micropyle also near this point.

Cane Sugar, or Sucrose. Common sugar, $C_{12}H_{22}O_{11}$.

Carpel. A simple pistil or an element of a compound pistil.

Carpophore. The prolongation of the pedicel between the carpels of umbelliferous plants, from which the carpels are suspended (p. 549; Fig. 480).

Caruncle. A wart-like excrescence formed on the micropyle of a seed.

Caryopsis. A dry, one-seeded, indehiscent fruit in which the seed adheres to the thin pericarp throughout, as in wheat and other grains.

Cell Nucleus. A globular protoplasmic body in the cell, instrumental in cell division (p. 23).

Cellulose. The carbohydrate forming the larger part of the cell-walls of young tissues.

Chaff. The glumes and palets of grasses.

Chalaza. The part of an ovule or seed where the integuments and nucellus unite (p. 35; Fig. 19).

Chartaceous. Papery.

Chlorophyl Grains. See *Chloroplasts.*

Chloroplasts, Chloroplastids, or **Chlorophyl Grains.** The characteristic bodies of green tissues, essential for photosynthesis (p. 29).

Chromatophores. See *Plastids.*

Chromoplasts, or **Chromoplastids.** Orange or yellow plastids, to which certain organs owe their color (p. 24).

Cleft. With narrow or acute divisions or sinuses extending half way or more to the midrib or base.

Collateral Fibro-vascular Bundle. With phloem and xylem in the same radial plane (p. 39).

Collenchyma. A tissue with conspicuous thickenings at the cell angles (p. 20; Fig. 3).

Column Cells. The subepidermal cells of the spermoderm of legumes, usually I-shaped or hour-glass-shaped (p. 239; Fig. 189).

Commissure. The surfaces of contact of the two fruits (merciarps) of the *Umbelliferæ* (p. 549).

Compound or **Multiple Fruit.** A fruit consisting of the ripened ovaries of several flowers.

Compressed Cells. See *Obliterated Cells.*

Concentric Fibro-vascular Bundle. With xylem encircling the phloem or *vice versa* (p. 44).

Conduplicate. Applied to seeds with cotyledons folded lengthwise about the radicle. (p. 173).

Conidium. See *Gonidium.*

Coniferous Plants, or **Conifers.** Gymnosperms bearing cones.

Convolute. Rolled up longitudinally from one margin.

Coriaceous. Leathery.

Cork. A protective tissue formed beneath the epidermis, especially of stems (p. 22; Fig. 512).

Corm. A short and thick, fleshy, subterranean stem, often broader than high, with roots on the lower side.

Corolla. The inner floral envelope, consisting of petals.

Cortex. The zone between the epidermis and phloem of annual stems, and between the cork and phloem of perennial stems (pp. 39, 40).

Cotyledons. The seed-leaves of the embryo.

Crenate. With margin having rounded teeth.

Cross Cells. Transversely elongated cells (p. 62; Fig. 36).

Cryptogamous Plants, or **Cryptogams.** The lower plants without stamens and pistils.

Crystalloids. Proteid crystals occurring in aleurone grains (p. 24).

Crystal Rosettes, or **Crystal Clusters.** Aggregates of crystals, particularly of calcium oxalate (p. 26; Fig. 8).

Crystal Sand. Deposits of minute crystals (p. 26; Fig. 10).

Cupule. The cup (involucre) of the acorn and similar fruits (p. 299).

Cuticle. The non-cellular membrane covering the epidermis (p. 21).

Cutin. The chief constituent of the cuticle.

Cystolith. A concretion of calcium carbonate occurring in special cells (Fig. 169).

Cytoplasm. The semi-fluid portion of the protoplasm (p. 23).

Dehiscent. Opening by valves, pores, or along regular lines.

Dentate. With margin having teeth pointing outwards.

Dextrin. A water-soluble carbohydrate intermediate between dextrose and starch.

Dextrose, or **Grape Sugar.** A sugar with the formula $C_6H_{12}O_6$, which turns the plane of polarized light to the right.

Dicotyledonous Plants, or **Dicotyledons.** Plants with embryo having two cotyledons. See *Exogenous Plants.*

Diœcious. With staminate and pistillate flowers on different plants.

Divided. With divisions extending quite to the midrib or base.

Dorsal Side. The outer side or back.

Drupe, or **Stone Fruit.** A fruit with a fleshy mesocarp and a hard endocarp or stone, such as the peach.

Drupelet. A small drupe.

Ellipsoidal. Applied to a solid elliptical in longitudinal section.

Elliptical. With the outline of an ellipse.

Emergence. A multicellular excrescence or hair with tissues derived from both the epidermal and hypodermal layers.

Embryo. The undeveloped plantlet in a seed (p. 38).

Embryo Sac. The sac in the nucellus in which fertilization is effected (p. 35; Fig. 19).

Empty Glumes. The two chaffy envelopes subtending a spikelet (Fig. 66).

Endocarp. The innermost layer of a pericarp (p. 35; Figs. 17 and 18).

Endodermis. The layer encircling the bundle zone (pp. 39, 45).

Endogenous Plants, or **Endogens.** Plants with bundles irregularly distributed through a parenchymatous tissue. The seeds have monocotyledonous embryos and the leaves are usually parallel-veined.

Endosperm. The albumen of the seed which, like the embryo, is developed in the embryo sac (p. 35).

Entire. Unbroken by divisions.

Epicarp. The outer epidermis of a fruit (p. 35; Figs. 17 and 18).

Epidermis. The outermost or innermost cell layer of an organ. See *Epicarp*.

Essential or **Volatile Oils.** Alcohol soluble mixtures of turpenes with other substances (p. 26).

Exogenous Plants, or **Exogens.** Plants with fibro-vascular bundles in a ring, forming new wood on the outside of the old. The seeds have dicotyledonous or polycotyledonous embryos and the leaves are usually netted-veined.

Fats and Oils. Compounds of fatty acids with glycerine (p. 26).

Fibro-vascular Bundle, or **Vascular Bundle.** A group of conducting elements consisting of xylem and phloem, with often a sheath of bast fibers (pp. 22, 39–45; Figs. 6, 231, and 232).

Filament. The slender stalk of the stamen bearing the anther.

Flowering Glume. The outer (lower) of the two envelopes subtending each flower of a spikelet of a grass (p. 60; Fig. 32).

Foramen. The opening at one end of an ovule through which the pollen tubes enter (p. 34; Fig. 19).

Fruit. The matured ovary and all it contains or that is connected with it (p. 33).

Fruit Coat. See *Pericarp*.

Fugaceous. Lasting but a short time.

Funiculus. The stem of an ovule.

Geniculate. Bent abruptly.

Glabrous. Smooth, i.e., free from hairs or bristles.

Gland. A modified cell secreting different substances. Loosely used for any slight swelling.

Glandular Hairs. See *Hairs*.

Glaucous. Covered with a bloom.

Globoids. Globular bodies occurring in aleurone grains (p. 25).

Glucosides. Compounds of sugars with organic acids.

Gluten Cells See *Aleurone Cells.*

Gonidium, pl. Gonidia. Same as *Conidium,* pl. *Conidia.* An asexual reproductive cell (p. 164).

Ground Substance. The material in which are embedded specially differentiated bodies, as the ground substance of aleurone grains (p. 24).

Ground Tissue. A tissue, usually parenchyma, in which others are embedded.

Guard Cells. The two crescent-shaped cells surrounding a stoma (p. 29; Figs. 11 and 12).

Gums. Mucilaginous substances soluble in water but precipitated by alcohol.

Gymnospermous Plants, or **Gymnosperms.** Phenogams having naked ovules.

Hadrome. See *Phloem.*

Hairs, or **Trichomes.** Unicellular or multicellular outgrowths of the epidermis (p. 29).

Hairs, Glandular. Hairs with a secretion chamber at the apex (Figs. 11 and 425).

Hastate. Halbert-shaped; with lobes at the base turned outwards.

Hemitropous, or **Amphitropous.** Applied to ovules or seeds with hilum midway between the chalaza and foramen (micropyle).

Hermaphrodite. With stamens and pistils in the same flower.

Hilum, pl. Hilums or **Hila.** (1) The scar or place of attachment of an ovule or seed to its funiculus or stalk; (2) the organic center of a starch grain (p. 647).

Hirsute. Rough hairy.

Hour-glass Cells. See *Column Cells.*

Hyaline. Transparent or translucent.

Hymenium. An aggregation of reproductive cells in a fungus (p. 420).

Hypha, pl. Hyphæ. A vegetative thread of a fungus.

Hypoderm. The layer or layers of cells immediately underlying the epidermis; here used chiefly for the hypoderm of fruits.

I Cells. See *Column Cells.*

Idioblast. A cell which differs greatly, in form, size, or contents, from the tissue in which it occurs.

Imbricated. Overlapping one another.

Incumbent. Applied to seeds with radicle against the back of one of the cotyledons (p. 173).

Indehiscent. Not opening by valves, pores, or along regular lines.

Inferior. Growing below some other organ. An inferior calyx is free from the ovary. An inferior ovary is united with the calyx tube.

Inflorescence. The arrangement of flowers on the stem, or a flower cluster itself.

Intercellular Spaces. Cavities between cells (Fig. 1).

Inulin. A water-soluble carbohydrate found in various roots. It forms sphæro-crystals in alcohol.

Invert Sugar. A mixture of equal parts of dextrose and levulose obtained by the inversion of cane sugar.

Involucre. A circle of bracts surrounding the base of a compound flower or a cluster of flowers.

Involute. Rolled longitudinally on the upper side from both margins.

Isodiametric. Having approximately equal dimensions.

Lanceolate. Much longer than broad, and tapering at the apex, or at both the apex and the base.

Latex Tubes. Branching tubes containing a milky secretion (Figs. 341 and 343).

Leptome. See *Phloem.*

Leucoplasts, or **Leucoplastids.** Colorless plastids instrumental in the formation of starch (p. 644; Fig. 570).

Levulose, or **Fruit Sugar.** A sugar with the formula $C_6H_{12}O_6$, which turns the plane of polarized light to the left.

Light Line. A bright line perpendicular to the axis of the cell seen in the palisade cells of legumes and other seeds (p. 234; Fig. 200).

Lignin. The characteristic constituent of woody or sclerenchymatized tissues.

Lobed. With rounded divisions or sinuses extending not more than half way to the midrib or base.

Locules. The cavities or macroscopic cells of a fruit or other organ.

Lodicules. The two very small hyaline scales between the base of a flower and its glume (p. 61).

Lumen, pl. **Lumens** or **Lumina.** The cavity enclosed by the walls of a cell.

Malpighian Cells. The palisade epidermis of leguminous seeds (p. 233; Fig. 200).

Mericarp. One carpel of the fruit of an umbelliferous plant (p. 549).

Meristem. A tissue, usually in a zone, forming other tissues by cell division.

Mesocarp. The middle layers of a pericarp (p. 35).

Mesophyl. The middle layers of a leaf (p. 29; Fig. 11).

Micropyle. The opening of a seed corresponding to the foramen of the ovule (Fig. 19).

Middle Lamella. The primary or middle layer between cells.

Midrib. The central nerve of a leaf.

Mitscherlichian Bodies. Multicellular hairs occurring on the epidermis of the embryo of the cocoa bean (p. 446; Fig. 348).

Monocotyledonous Plants, or **Monocotyledons.** Plants with embryos having one cotyledon. See *Endogenous Plants.*

Monœcious. With staminate and pistillate flowers on the same plant.

Morphology. The study of vegetable parts with reference to their form, origin, and metamorphoses.

Mycelium, pl. **Mycelia.** The vegetative portion of a fungus consisting of hyphæ.

Naked Fruit. A fruit readily separating from its envelopes.

Nucellus. The body of the ovule (p. 35; Fig. 19).

Nucleus. See *Cell Nucleus.*

Nutritive Layer. A layer of the spermoderm, several cells thick, containing starch or other contents which are translocated to other parts during ripening.

Obliterated Cells. Compressed cells with little or no evidence of their cellular structure.

Obovate. With the outline of a longitudinal section of a hen's egg; attachment at the smaller end.

Obovoid. Egg-shaped with attachment at the smaller end; solid obovate.

Oil Cells. Cells secreting fatty or essential oil.

Oil Ducts. Ducts containing essential oil, as the vittæ of umbelliferous fruits (p. 549).

Orthotropous. Applied to ovules and seeds with both hilum and chalaza at the point of attachment, and the foramen or micropyle at the opposite end.

Oval. Broadly elliptical.

Ovary. The body of the pistil in which are contained the ovules and which later develops into the fruit (Fig. 19).

Ovate. With the outline of a longitudinal section of a hen's egg; attachment at the larger end.

Ovoid. Egg-shaped with attachment at the larger end; solid ovate.

Ovule. A body contained in the ovary which, after fertilization, develops into a seed.

Palet, or **Palea.** The upper (inner) of the two envelopes subtending each flower of a spikelet of a grass (p. 60, Fig. 32).

Palisade Cells. Elongated cells arranged perpendicular to the surface, resembling in cross section a palisade (Fig. 166).

Palmate. With divisions radiating from the end of the stem, like the fingers of a hand.

Panicle. A loose, branching flower cluster.

Papilionaceous. Butterfly-shaped, such as the flowers of the pea.

Papilla, pl. **Papillæ.** Soft nipple- or club-shaped protuberances.

Pappus. The modified calyx lobes, consisting of bristles, hairs, teeth, or a cup, which crown the achenes of the *Compositæ.*

Parenchyma. The simplest form of tissue, such as pith, mesophyl, etc. (p. 20; Fig. 1).

Parenchyma, Spongy. A loose parenchyma with pronounced intercellular spaces (p. 20; Fig. 2).

Parqueted Cells. Elongated cells arranged in groups, those in the same group side by side and extended in a different direction from those in other groups (Fig. 472).

Parted. With divisions extending almost to the midrib or base.

Pedicel. The stem of a single flower of a group.

Peduncle. The stem of a solitary flower or a group of flowers.

Perianth. The floral envelopes, consisting of calyx, or calyx and corolla.

Pericambium. See *Pericycle.*

Pericarp, or **Fruit Coat.** The matured ovary wall (p. 33; Figs. 17 and 18).

Pericycle. The outer layer of the stele, adjoining the endodermis (p. 40).

Periderm. The outer bark, consisting chiefly of cork cells.

Perisperm. The part of a seed developed from the nucellus of an ovule (p. 38; Fig. 20).

Petals. See *Corolla.*

Petiole. The stem of a leaf.

Phanerogamous Plants, or **Phanerogams.** The higher plants having true flowers with stamens and pistils.

Phelloderm. The tissue formed on the inner side of the phellogen.

Phellogen. The meristematic layer forming cork on the outside and phelloderm or secondary cortex on the inside.

Phenogamous Plants, or **Phenogams** (also spelled *Phænogams*). See *Phanerogams.*

Phloem, Bast, or **Leptone.** The softer part of a fibro-vascular bundle, consisting of sieve-tubes, cambiform cells, and other non-lignified elements (p. 22).

Photosynthesis, or **Assimilation.** The formation through the agency of light of organic matter in chlorophyl tissues from carbonic acid and water (p. 28).

Pigment Cells. Cells containing coloring matter.

Pinnate. Arranged on both sides of an axis, like the vanes of a feather.

Pistil. The female element of the flower, consisting of ovary, style, and stigma.

Pith. The central parenchymatous core of exogenous roots and stems.

Pits. See *Pores.*

Placentæ. The parts of the ovary bearing the ovules.

Plastids, or **Chromatophores.** Protoplasmic grains, including chloroplasts, leucoplasts, and chromoplasts (p. 23).

Plumule. The bud or growing point of the embryo above the cotyledons (Fig. 62).

Polarization Crosses. Dark crosses seen on starch grains when examined under the micro-polariscope with crossed Nicol prisms.

Pollen Grains. The fecundating powder formed in the anthers.

Pollen Tubes. The tubes formed on pollen grains which penetrate the ovule and effect fertilization (Fig. 19).

Pome. A fleshy fruit with united receptacle and pericarp, such as the apple.

Pores, or **Pits.** Openings or depressions in cell walls, affording communication between adjoining cells.

Procambium. The elongated cells of the embryo from which the fibro-vascular bundles are developed.

Proteids, or **Albuminoids.** A class of substances containing about 16 per cent of nitrogen, to which belong gluten, legumen, etc. (p. 24).

Protoplasm. The living matter of the cell, consisting of cytoplasm, cell nucleus, and plastids (p. 23).

Pubescent. Soft hairy.

Raceme. A flower cluster with one-flowered pedicels arranged along a common axis.

Rachis. The axis of a spike or of a compound leaf.

Radial Fibro-vascular Bundle. With phloem and xylem in different radial planes alternating with each other (p. 45).

Radial Walls. Walls perpendicular to the surface of an organ.

Radicle. The stem of the embryo, from the lower end of which develops the root.

Raphe. The strand of vascular elements joining the hilum of a seed with the chalaza (p. 35; Fig. 19).

Raphides. Needle-shaped crystals (Fig. 9).

Receptacle. The immediate support of a group of flowers or other organs.

Reniform. Kidney-shaped.

Reserve Material. Starch, oil, proteid, or other materials stored for future use in seeds, stems, rhizomes, tubers, and other organs.

Reserve Starch. Starch deposited in seeds, rhizomes, tubers, and other organs for future use (p. 643).

Resins. Solid oxygenated hydrocarbons related to the essential oils, insoluble in water but soluble in ether, essential oils, etc.

Respiration. The oxidation of organic matter in the leaf with exhalation of carbonic acid (p. 28).

Reticulated. Netted.

Reticulated Vessels. With thickenings forming reticulations. Intermediate forms occur between these and spiral vessels.

Revolute. Rolled longitudinally on the under side from both margins.

Rhizomes, or **Rootstocks.** Stems or branches growing beneath or partly covered by the soil.

Sagittate. Arrow-shaped; with lobes at the base turned downwards.

Scalariform Vessels With transversely arranged ribs in rows like the rounds of a ladder (Fig. 6).

Sclerenchyma. A tissue with thickened and lignified walls, such as stone cells and bast fibers.

Sclerotic Cells. See *Stone Cells.*

Sclerotium, pl. **Sclerotia.** A compacted mass of sterile hyphæ forming the resting stage of certain fungi (p. 164; Fig. 141).

Scutellum. A shield-like sucker (cotyledon) on the side of the embryo in grasses (p. 61; Fig. 62).

Secondary Cortex. The cortex formed by the phellogen outside of the primary cortex.

Seed. The fertilized and matured ovule.

Seed Coat. See *Spermoderm.*

Sepals. See *Calyx.*

Serrate. With margin having sharp teeth pointed forwards.

Sieve Plates. The perforated plates forming the cross partitions of sieve tubes and occurring also on the side walls.

Sieve Tubes. The characteristic elements of the phloem, consisting of soft tubes with perforated cross partitions (p. 23; Figs. 6 and 25).

Silica Cells. Conical cells, corresponding to hairs, found on the epidermis of the glumes and palets of certain cereals (p. 62; Fig. 45).

Silicle. A short *silique.*

Silique. The pod of the *Cruciferæ,* opening from below by two longitudinal valves, leaving the seeds attached to the placentæ.

Sinuous, or **Sinuate.** With deeply wavy margins.

Sinus. A cove or re-entrant angle.

Spathe. A large bract encircling a flower cluster.

Spatulate. With rounded apex and narrow, tapering base.

Spermoderm, Testa, or **Seed Coat.** That portion of the skin or shell of a seed developed from the integuments of the ovule (p. 37).

Sphacelia, the active stage of ergot (p. 164).

Spike. A group of sessile flowers on a common axis.

Spikelet. In grasses, a group of flowers subtended by two empty glumes (p. 60; Fig. 32).

Spiral Vessels. Vessels with spiral thickenings, resembling a spiral spring (Fig. 6).

Spongy Parenchyma. See *Parenchyma.*

Spores. The reproductive bodies of cryptogams, analogous to the seeds of phanerogams.

Stamens. The male elements of the flower, made up of filament and anther.

Starch (Latin *Amylum*). A carbohydrate with the formula $(C_6H_{10}O_5)_n$, occurring as grains insoluble in water.

Stegmata, pl. Cells containing silicious bodies (Fig. 232).

Stele. The central cylinder of a stem or root within the endodermis (p. 40).

Stigma. The end portion of the pistil on which are deposited the pollen grains.

Stoma, pl. **Stomata;** or **Stomate,** pl. **Stomates.** The openings or breathing pores of epidermal tissues, particularly of leaves (p. 29; Figs. 11 and 12).

Stone Cells, or **Sclerotic Cells.** Sclerenchyma elements, either isodiametric or moderately elongated, with thick, porous walls (p. 21; Fig. 4).

Stone Fruit. See *Drupe.*

Style. The neck of the pistil connecting the stigma with the ovary.

Subepidermal Layer. The layer of cells immediately underlying the epidermis. Here used chiefly for the subepidermal layer of seeds.

Suberin. The characteristic constituent of cork tissues.

Subtend. To extend underneath.

Sucrose, or **Cane Sugar.** Ordinary sugar with the formula $C_{12}H_{22}O_{11}$.

Superior. Growing above some other organ. A superior calyx is grown to the ovary i.e. adnate. A superior ovary is free from the perianth.

Suture. A seam of union, or line of dehiscence.

Tannins. Colorless astringent substances, becoming brown on drying, which are colored blue or green by iron salts.

Testa. See *Spermoderm.*

Terrete. Circular in cross section.

Tracheæ. See *Vessels.*

Tracheids. Elongated, lignified cells of the xylem, distinguished from vessels by their cross partitions (Fig. 232).

Transitory Starch. Starch temporarily deposited in an organ (p. 643).

Transpiration. Exhalation of water through the leaf.

Trichomes. See *Hairs.*

Tube Cells. Longitudinally arranged vermiform cells, especially those forming the endocarp of cereals (p. 62; Fig. 36).

Tuber. A thickened portion of a subterranean stem.

Twin Cells. Pairs of oval or crescent-shaped cells found on the epidermis of the glumes and palets of certain cereals (p. 62; Fig. 45).

Ventral Side. The inner side, facing the axis.

Versatile. Swinging freely on its support.

Vessels, or **Tracheæ.** The lignified ducts or tubes of a fibro-vascular bundle, distinguished from tracheids by the absence of transverse partitions (p. 22; Figs. 6 and 25).

Vittæ. Oil ducts of umbelliferous fruits (p. 549).

Volatile Oils. See *Essential Oils.*

Water Pores, or **Water Stomata.** Epidermal openings situated at the ends of the nerves of leaves, through which water is discharged.

Wavy. Curving gently in and out.

Xylem, Wood, or **Hadrome.** The portion of a fibro-vascular bundle containing the vessels and tracheids (p. 22; Figs. 6, 231, and 232).

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