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RUDIMENTS

OF

VEGETABLE PHYSIOLOGY.

FOR USE IN SCHOOLS AND IN PRIVATE INSTRUCTION.

REVISED AND IMPROVED,

BY

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INTRODUCTION

BY

THE AMERICAN EDITOR.

The subject of this volume, which appropriately follows that of Animal Physiology, is perhaps the most difficult to adapt to the object of this series, of either of the departments of physical science. This difficulty arises not from any intrinsic obscurity in the subject itself, nor in any lack of interest in the topics of inquiry, for the subject is both easy and delightful, and is uniformly found to awaken enthusiasm in the young, especially if pursued practically. But the obstacle in the way of adapting it to the use of schools, is found in the multitude of technical terms which, whatever we may do in other sciences, can neither be substituted nor dispensed with in this. The minute and complicated anatomy of plants abounds in variegated organs, appendages, tissues, and other peculiarities of structure, the discrimination of which requires the use of a multitude of technicalities, such as have, for the most part, no synonyms. They are, however, very significant, and will soon become familiar by repetition. The physiological department, strictly such, will be found encumbered with no less difficulty, which, as in the former case, admits of no remedy, and must therefore be met and overcome.

The author appears to have done all that is practicable in the way of definition and illustration, and hence very little improvement of the text has been attempted. The teacher who will use this volume for the purpose of instruction, will find upon every page an analysis of the subjects treated, in the form of catechetical questions, which will afford him facilities. And if he will accompany his pupils upon botanical excursions, and assist them in the dissection of plants and flowers, and the preparation of Herbaria for collecting and preserving specimens, he will find such practical exercises greatly to facilitate the study. The copious index appended will serve as a glossary, nor is any other needed.

In the hope that this edition will be useful in prompting to the cultivation of this beautiful subject in schools, it is respectfully submitted to teachers of youth as worthy of their adoption.

THE AMERICAN EDITOR.

PREFACE.

The following Treatise is intended to present an outline of an interesting, but as yet imperfectly investigated, Science—that which refers to the Economy of Plants. In vegetables, though the organs be of simple structure, the mode in which these perform their functions is so obscure that Physiologists have been able to ascertain only a few of their more obvious operations. Besides, VEGETABLE PHYSIOLOGY, as this branch of knowledge is technically entitled, is of comparatively recent origin—it being scarcely half a century since the vital actions of plants became the subject of actual experiment; earlier botanists contenting themselves with vague analogies, drawn from the more apparent functions of Animal Organization. In this imperfect but progressive state of the science, all that is aimed at in the subsequent pages is to convey to the learner an idea of the General Structure and Functions of Plants—their various Organs, and the Terms by which these are respectively distinguished—their modes of Growth and Reproduction—their Geographical Distribution—and their extensive Utility in the Scheme of Creation. In doing so, we have endeavoured to avoid technicalities as much as is consistent with accuracy, and to present, in a familiar manner, only the principal facts admitted by modern botanists, in order that the Treatise might answer the end intended—namely, for Use in Schools, and for Private Instruction.

The Classification and Description of Plants, having reference more to individual types and resemblances than to the general principles of Vegetation, are reserved as the subject of another volume, under the title of SYSTEMATIC BOTANY.

Edinburgh, January, 1844.

CONTENTS.

VEGETABLE PHYSIOLOGY.

GENERAL ECONOMY OF VEGETATION.

NATURE AND FUNCTIONS OF PLANTS.

1. Vegetable Physiology is that department of natural science which explains the organization and vital functions of plants.

2. *Plants, animals, and minerals,* are all formed by the chemical combination of certain elements. In minerals these elements combine by the force of chemical affinity only, but in plants and animals they are held in combination by vital action.

3. *Vitality* enables plants and animals to absorb and assimilate food, consisting of the elements necessary for their increase, and also to reproduce beings of their own kind, by means of certain organs: hence they are said to be *organized*, and the substances of which they are composed are known by the general name of *organic matter*. Minerals not possessing vitality have no organs, and consist only of *inorganic matter*.

4. *Animals* feed partly on other animals, and partly on plants; and plants feed partly on organic matter when decomposed, and partly on inorganic. Thus minerals, by the beautiful economy of nature, contribute towards the support of animals through the medium of plants.

5. *The elements* of which organized bodies are composed, separate or decompose as soon as life has fled,

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1. Define vegetable physiology.
2. Difference between the combination of elements.
3. Modifications resulting from vitality.
4. The food of animals and plants, respectively.
5. What brings organic matter under the laws of chemical affinity?

being attracted to other bodies by the force of chemical affinity.

6. *The simplest forms of life* are observable in certain plants and animals, whose economy is limited to the absorption and assimilation of nutriment, and the power of reproduction; and the difference between these inferior plants and animals is so trifling, that in them the animal and vegetable kingdoms seem to pass into each other. Thus, certain tribes of zoophytes, and some kinds of algæ, or sea-weed, are so very nearly allied both in appearance and habits, that they can scarcely be distinguished from each other scientifically; and, indeed, the same object has been occasionally classed as a plant by one naturalist, and as an animal by another.

7. *The scientific differences between plants and animals* are difficult to define, when they are to be applied to all plants and to all animals. Few plants possess the power of locomotion; but the aquatic plant called the fresh-water sailor detaches itself from the mud in which it grows originally, and rises to the surface of the water to expand its flowers. Plants are propagated by division, which most animals are not; but the polypes of the coral reef grow united like the buds of a plant clustering round a common stem from which they receive their nutriment, and, when separated, become each perfect individuals. Plants are said to have no stomach; but the lobe-like leaves of Venus's fly-trap possess the power of digesting the flies they catch; and though plants are said to be without feeling, the leaves of the sensitive plant shrink from the slightest touch. In like manner the pith of young trees and shrubs has been compared to the spinal marrow of animals; the upward current of the sap in spring, and its descent in summer or autumn, to the circulation of the blood; and the exhalation of oxygen and absorption of carbonic acid gas in the leaves, to respiration; but beyond a faint analogy there is nothing like identity between the respective func-

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6. What are the simplest forms of life ?
7. Is the line of demarcation between plants and animals distinct ?
8. Wherein is the analogy supposed to approach identity ?

tions of plants and animals. Indeed, all the vital functions of plants are performed in a manner different from those of animals; the instances of locomotion, sensitiveness, and power of digestion in plants, being very rare and imperfect, while the power of propagating by division in animals is equally so.

8. *Plants derive their food* partly from the soil, and partly from the air; and whatever they take must either be reduced to a liquid, or to a gaseous state. The elements of which plants are composed are, Carbon, Oxygen, Hydrogen, and Nitrogen. Of these, Carbon, which is a solid substance, is the principal; and, as it is insoluble in water, it must be combined with oxygen, so as to form *carbonic acid gas*, before it can be taken up by plants. Oxygen is the next in abundance, and it is absorbed principally when combined with nitrogen, in the form of atmospheric air. Hydrogen is not found in a free state in the atmosphere, and therefore it can only be taken up by plants when combined with oxygen, in the form of water, or with nitrogen, as ammonia, in which last form it exists in animal manure. Nitrogen, though found in very small quantities in plants, is a most important element, as it forms the principal ingredient in the *gluten*, which is the most nutritive part of corn and other seeds, and which is essential to the germination and first nourishment of young seedling plants. Nitrogen also appears to be a principal agent in the production of colour in leaves and flowers, especially when they first expand.

9. *As oxygen is imbibed by plants in combination with all the other elements of which they are composed*, it is not surprising that the plant takes up more of this gas than it requires; and, consequently, it has been furnished with a remarkable apparatus in the leaves, to enable it to decompose the carbonic acid, and other gases which it has absorbed, and to part with the superfluous oxygen. Plants are

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9. Repeat the illustrations, and the inference best authorized.
10. Source of the food of plants, and the form or state necessary.
11. What of carbon,—of oxygen,—of hydrogen?
12. Where do they obtain hydrogen and nitrogen?

thus found to improve the air by the removal of carbonic acid, which is injurious to animal life, and by the restoration of oxygen, which is favourable to it; and so to maintain a necessary equilibrium in the atmosphere, as animals are continually absorbing oxygen, and giving out carbonic acid. In hot swampy countries, however, where vegetation is extremely rapid, and the soil surcharged with decaying vegetable matter, plants absorb more carbonic acid than they want, and give out the superfluity through their leaves; and hence, warm moist climates, such as those of some of the West India islands, though extremely favourable to vegetation, are equally injurious to human life.

10. *Light being essential to the decomposition of carbonic acid gas in the leaves*, oxygen is not exhaled by plants during the night; but, on the contrary, a small quantity of carbonic acid gas escapes, and oxygen is absorbed. These processes have been called the respiration of plants; but they are very different from the respiration of animals, the first being mechanical, and the second chemical, and both totally unconnected with the assimilation of food. When the soil abounds in carbonic acid gas and in moisture, the roots of a plant must continue constantly absorbing that moisture mixed with the carbonic acid; and this carbonic acid rising to the leaves, escapes in its original state when there is no light to decompose it. The absorption of oxygen is a chemical process, which appears to go on whenever the process of assimilation has ceased—in dead plants as well as in living ones. When leaves have ceased to act in decomposing carbonic acid, and assimilating or fixing the carbon in autumn, oxygen is absorbed so rapidly as to change their colour to some shade of red; fruit, when fully swelled, ceases to assimilate carbon, and becomes intensely acid by the absorption of oxygen; and, finally, the decay

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13. What improvement of the air results from the leaves of plants?
14. What of hot swampy countries?
15. How are plants affected by the presence or absence of light?
16. Describe the mechanical and chemical process, which has been called the respiration of plants.
17. What occasions the red colour of leaves in autumn?
18. What hastens the decay of vegetable matter?

of all vegetable texture is hastened by the absorption of the same element. Thus, as the assimilation of carbon ceases during the night, oxygen is absorbed at that period in quantities that vary according to the nature of the plant; those plants which have acid, or highly-flavoured juices, absorbing most. Thus, Liebig tells us that the tasteless leaves of the American aloe, if kept in the dark twenty-four hours, absorb only 0.3 of their volume of oxygen in that time; while the leaves of the spruce fir, which contain volatile and resinous oils, absorb ten times, those of the common oak, which abound in tannin, fourteen times, and those of the balsam poplar, twenty-one times as much. The chemical action of oxygen on vegetation is strikingly exemplified in the leaves of a species of navel-wort, which are acid in the morning, tasteless at noon, and bitter at night. The acid is caused by the accumulation of oxygen during the night, the insipidity by the mixture of the oxygen with hydrogen, and the bitter flavour by an excess of hydrogen.

11. *Plants are of important service in the general economy of nature*, as well as of direct advantage to the arts and sciences. The quantity of carbonic acid which they are continually absorbing from the atmosphere during the day, serves to purify it from the immense quantity of carbon continually disengaged from the lungs of human beings and the lower animals, and from the combustion of fuel; while the oxygen with which the carbon was combined, is restored, to be again employed. Plants also act as the medium through which inorganic matter is made to contribute to the support of animal life; while they invest the landscape at once with beauty and amenity, by the variety of their hues and the shelter of their foliage.

DEVELOPMENT AND GROWTH OF PLANTS, AS DEPENDENT ON AIR, HEAT, MOISTURE, LIGHT, AND SOIL.

12. *The development of vegetable life* depends upon the

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19. Differences in absorbing oxygen, and effects.
20. Uses of plants in the economy of nature.
21. Upon what agents is vegetable life dependent?

concurrence of certain agents, the principal of which are—*heat, air, moisture, light,* and *soil.*

13. *No seed can germinate* without the concurrence of the three agents of heat, air, and moisture; but in the *growth* of plants, the agency of soil and light is also necessary.

14. *Every perfect seed contains the germ or embryo of a new plant* of the same kind as the parent, and a portion of concentrated carbon and nitrogen, in the form of starch and gluten, laid up to serve as nutriment for the young plant, till its organs are sufficiently developed to enable it to seek food for itself. The seed is generally enveloped in a hardened case, in order to preserve it in an inert state as long as may be necessary.

15. *As soon as a seed is put into the ground,* it is acted upon by the influence of heat and moisture, which distend its particles, and make them burst the integument that envelopes them. The agency of the air is next required to combine with the store of nutriment laid up in the seed, and to fit it for the purpose of vegetation.

16. *The first organ that expands* in the embryo of a young plant is the root; and nature has provided a small opening in the covering of a seed, towards which the point of the root is always turned, in order that it may be protruded without injuring its soft and delicate texture. The root takes up water and air, and transmits the liquid thus formed to the seed leaves, in which it is exposed to the influence of light.

17. *The nutritive substances laid up in the seed* become quite changed during the process of germination. The starch, which is insoluble in water, is rendered soluble by the action of a peculiar substance called *diastase,* derived from the gluten. This substance has so powerful an effect upon the starch as to render it instantly soluble in the sap, and thus the nutriment is gradually prepared for the use of

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22. What of germination and growth?
23. Name the elements of every perfect seed, and their use.
24. Effects of heat and moisture upon seed.
25. What is peculiar in reference to the root?
26. Describe the changes during germination.

the infant plant. As the sap ascends it becomes sweet; the starch is changed into sugar, and this sugar, again, into woody fibre as the tip of the plant emerges into light. When the store of starch and gluten has been exhausted, the plant is able to live by its own assimilating powers, at the expense of the air and the soil.

18. *Heat*, though essential to germination, is injurious, unless it be combined with moisture. A high degree of dry heat will parch seeds, and destroy their vitality; and hence, when they are to be kept for food, it is not unusual to dry them in an oven, to prevent them from germinating. When combined with moisture, a very high temperature is not injurious to vegetation; and, indeed, some kinds of moss have been found growing near hot springs in Cochin China, where they must have vegetated in a heat equal to 186 degrees; on the other hand, in cold climates, mosses, some kinds of grass, and chickweed, are found to vegetate at 35 degrees, or even only just above the freezing point. Warmth is not only necessary for the germination of the seed, but also for the growth and after development of the plant. The sap will not rise without a certain degree of heat; and it is well known that frost stops its current. Cold will also check the development of the flowers and fruit, and even of the leaves, and will prevent the full flavour being attained by the fruit. The secretions of plants are diminished by cold. The fruit of the walnut and the beech produce oil in the south of Europe, which it will not do in Britain; and the leaves of the mulberry grown in this country will not afford the same quantity of caoutchouc to the silkworm as in France and Italy.

19. *Moisture* must be combined with heat and air to render it useful to vegetation. An excess of moisture without heat, and combined with air, induces decay in seeds, instead of exciting them to germinate; and an excess of moisture is injurious even to growing plants, as it destroys the delicate tissue of the spongioles of their roots. When trees

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27. Necessary union of moisture with heat.
28. What of the importance of heat to growth and secretion?
29. What is the effect of moisture, uncombined with heat and air?

are grown in situations where they have abundance of heat and moisture, but where the roots are beyond the reach of air, they have a tendency to produce leaves instead of fruit and seeds, and all their secretions are weakened. On the other hand, too little moisture prevents the leaves and fruit from attaining their proper size and form. A sudden deprivation of moisture causes the leaves to droop and the fruit to fall off.

20. *Air* is essential both to the germination of the seed and the development of the plant. Without oxygen from the atmosphere, the carbon laid up in the seed cannot be made available for the use of the infant plant, as carbon in its concentrated state is insoluble in water, and requires to be combined with oxygen to convert it into carbonic acid gas, before it can be absorbed by the vessels. In like manner, air is essential through all the processes of vegetation; no wood can be formed, no seed. ripened, and no secretions produced, without abundance of carbon; and this cannot enter the plant, even from the soil, without a constant supply of oxygen from the air. The greater part of the carbon in plants is indeed derived directly from the air by the leaves, in the shape of carbonic acid gas—a minute quantity of which is always found in combination with the atmosphere.

21. *Light* is not required for the germination of seeds, but it is essential to the development of plants, as it occasions the decomposition of the carbonic acid contained in the vessels of all the parts exposed to its influence; without which the plant could not assimilate the carbon to its own use. Colour also appears to depend partly on light. Plants grown in darkness are most deficient in colours which contain blue. The leaves and other parts, which should be green, are frequently reddish, from the retention of oxygen, or yellowish, from the superabundance of nitrogen, while the flowers and fruit are whitish. Frequently, the whole plant is whitish, in which case it is said to be *etiolated*, or blanched.

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30. Importance of air to vegetation, and why?
31. Uses of light, and illustrations.

22. *The soil* serves not only as a bed for the plants to grow in, but also contributes to their nourishment. In addition to the elements of which they are principally composed, there is always found in their substance a small quantity of inorganic matter, which differs according to the nature of the plant, and which appears to be derived solely from the soil. The proportion which this matter bears to the whole will be found by burning part of the plant in the open air; when the inorganic matter, being indestructible by fire, will be left in the form of ashes. Soils are of various kinds, and they are produced principally by pulverized particles of rocks, being disengaged by the action of heat, air, and water, and mixed with decaying animal and vegetable substances.

23. *There are four primitive earths*, called *clay, sand, lime*, and *magnesia;* the first three of which are found more or less in almost every soil, and generally with only a very small proportion of the latter. Clay, which is also called *alumina*, or *argillaceous earth*, or *earth of alum*, predominates in some soils, and these are generally unfertile; as the particles of clay are too adhesive to allow the free passage of either air or water to the roots of plants. A soil of this kind also offers obstacles to the expansion of fibrous roots; and when it admits water, it retains it so long as to be injurious. Sand, which is also called *silex, silica*, or *siliceous earth*, consists, on thè other hand, of particles which have generally too little adhesion to each other; and it is injurious to plants, partly from its incapability of retaining sufficient water for their nourishment, and partly because it admits too much solar heat to their roots. When the particles of sand adhere to each other, they form sandstone, or some other mineral substance equally impenetrable by roots. Lime is never found in a pure state in nature, but always combined with some acid. The common carbonate of lime or limestone is of no use

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32. Uses of the soil, and what of inorganic matter?
33. Name the four primitive earths.
34. Define clay, its nature and effects in soil.
35. What is sand in soils?
36. Nature of the combinations of lime in soils, and magnesia?

in vegetation till it has been burned—that is, till the carbonic acid, water, and other matter it may contain, have been driven off by heat. In this state it is called caustic lime, and is used as a manure, as it has a great affinity for carbonic acid, which it is continually drawing into the soil from the atmosphere or other sources. Chalk, or the earthy carbonate of lime, is well adapted for vegetation, but it is generally cold, as, from its whiteness, it reflects the solar rays instead of absorbing them. Magnesia is very similar to lime, but is less abundant. It generally occurs in combination with lime, in what is called magnesian limestone. Notwithstanding the whiteness of chalk, calcareous soils—that is, soils containing some form of lime—are generally black, from the quantity of vegetable matter which they contain in proportion to the depth of the soil. All soils containing a great proportion of decayed vegetable matter are black; and black soils, though generally warm, from the power they possess of absorbing solar heat, are seldom productive, unless they be dry. Thus, black peat, or bog earth, which is moist, is unproductive, while heath mould, mixed with sand, which is dry, is very useful for many kinds of crops. The reason is, that decayed vegetable matter, or *humus*, is insoluble in water, and consequently cannot be taken up by plants until the carbon it contains is combined with oxygen, so as to form carbonic acid gas, which it can only do when the humus is kept sufficiently dry to allow of its particles being exposed to the free action of the air.

24. *It must be observed, that no soil consists of any one of the primitive earths alone*, and that most soils contain all of them combined in different proportions, and mixed with other ingredients. These are saline particles of various kinds, potash, soda, and other alkalies, iron, and several other minerals, in combination with the different acids—all of which are designated, when speaking of the food of plants, by the general name of *inorganic matter*.

25. *Plants require different kinds of inorganic matter*,

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37. What is said of black soils, their variety?
38. Name the inorganic matter of soils, other than earths.

according to their nature, and appear to possess the power of selection, as they only take the kind they need, though it may form but a very small portion of the soil in which they grow. Thus, it is evident that any particular crop must in time exhaust the soil in which it grows of the requisite inorganic matters, unless they should be renewed by the addition of what are called mineral manures; and it is also clear that crops requiring another kind of earth, may succeed in the same soil, after it has become unproductive for the first kind of crop. This, according to modern doctrines, explains the necessity which is known to exist for what is called *the rotation of crops*—that is, for letting crops of a different nature succeed each other in fields and gardens. The necessity for this rotation was supposed by De Candolle and others to arise from plants poisoning the soil with the excrementitious matter which they were supposed to eject by their roots; but while this hypothesis was believed, it appeared difficult to account for the well-known fact, that the same crops may be grown perfectly well in any soil for an indefinite number of years, provided that soil be frequently and properly manured—that is, supplied afresh with the ingredients of which it has been exhausted by the plants.

26. *Nature, when unassisted, invariably changes the crops of plants* whenever occasion for such a change occurs; and if a forest of North America should be accidentally burned down, trees of quite a different nature are sure to spring up in the room of those that have been destroyed. These changes are effected in various ways. Many seeds are furnished with downy wings, on which the wind bears them far away from their parent plant; and other seeds burst from their seed-pods with such elasticity, as to be scattered to a considerable distance. Suckers from under-ground stems, and runners of various kinds, are other means by which plants are enabled to obtain nourishment from fresh

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39. Is there any thing like elective affinity to soils of a peculiar kind on the part of plants?
40. What of the necessity of rotation of crops?
41. How are the changes of crops of plants to be accounted for occurring spontaneously?

soils when they have exhausted that in which they originally grew; and nature has afforded similar powers to even the largest forest trees, by enabling them to elongate their roots to any extent that may be required.

27. *Plants do discharge matter from their roots,* but it is generally of the same nature as the peculiar secretions of the plant; as, for example, the matter exuded by the roots of the poppy has the properties of opium, that from the oak tannin, &c. The excretory matter is thus evidently part of the elaborated or most perfect kind of sap.

TERM OF VEGETABLE EXISTENCE.

28. *The longevity of plants* differs according to their nature, and the circumstances in which they are placed.

29. *Herbaceous plants,* the stems of which are succulent, and full of juice, are divided into three kinds, according to the term of their existence; namely, *annuals,* which grow only one season, and die as soon as they have ripened their seeds; *biennials,* which generally last only two years; and *perennials,* which last several years. To these, practical horticulturists sometimes add a fourth kind, consisting of such as last three or four years, but no longer, and which have no distinctive name, though they are generally classed with biennials.

30. *Trees and shrubs,* which have *ligneous,* or woody stems, are destined to remain undecayed for years. Shrubs are those ligneous plants which have several stems springing from the same root, all nearly of the same thickness. They seldom last above thirty or forty years, and frequently not half that time; but trees which have only one stem or trunk proceeding from the root to a considerable height before it divides into branches, generally endure for a long period of time—in several instances even for centuries.

31. *The length of time which trees live* depends in a great measure on the situations in which they grow. If a tree which is a native of mountains be placed in a valley,

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42. What discharge proceeds from the roots of plants?
43. What of the longevity of herbs, trees, and shrubs?
44. What circumstances vary the longevity of trees?

it grows more rapidly, but the term of its existence is shortened, and its timber becomes softer and of less value. In like manner, if the tree of a valley be grown on a mountain, the term of its existence is lengthened, and its trunk, though of slow growth and small dimensions, produces timber remarkable for its toughness and durability; as, for example, the Highland oak.

32. *The age of trees was formerly calculated* by their diameter, or by the number of their concentric circles; but both these modes are found to be fallacious. According to the first it was supposed that if a tree attained the diameter of a foot in fifty years, fifty years should be counted for every foot it measured in diameter; and thus it was supposed that the great baobab tree, found by Adanson on the banks of the Senegal, which measured nearly thirty feet in diameter, must have been about six thousand years old, or coeval with the world itself. It is now found, however, that the baobab, like all soft-wooded trees, grows rapidly, and attains an enormous diameter in less than a hundred years. The mode of counting by concentric circles only applies to exogenous trees, and even with them it is very uncertain. A warm spring, which sets the sap early in motion, followed by weather cold enough to check vegetation, will give the appearance of two layers in one year, as the recommencement of vegetation will have the same appearance as a new layer in spring. In many trees, such as the oak, for example, a second growth often takes place after midsummer; so that even a third layer is occasionally formed in the course of six months. On the other hand, a moist warm winter, by keeping the tree growing the whole year without any check to vegetation, will give the appearance of only one layer to the growth of two years. Notwithstanding these anomalies, practical men find counting the concentric circles of a tree the best mode which has yet been discovered of ascertaining its age, as in ordinary cases only one growth is made in the course of a year.

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45. What modes of ascertaining the age of trees are cited?

33. *The natural decay and death of plants* appear to follow the same laws as the natural decay and death of animals. When a tree approaches the term of its existence, the sap flows more feebly through its vessels, and it is no longer propelled through every part. As this takes place, the parts no longer visited by the sap die; and as soon as life has fled, the opposition principle of chemical affinity begins to act, and the various elements that composed the plant fly off, to combine with other elements, so as to form new substances. This is the natural process which takes place invariably with every organized being; the fall of the leaf, and the dropping of the ripe fruit, are but the death of both when fully matured; and in the like manner death is followed in both instances by its natural attendant, decomposition. [Death, however, in the case of the family of man, is ascribed in the Scriptures to Divine appointment, as the consequence of sin. A large majority of our race die in infancy, instead of perishing by this "natural process" at maturity. So that the analogy must not be understood to apply to man among the animals whose decay and death follow the same laws as in the case of the leaf or an apple.]

SIMPLE OR ELEMENTARY ORGANS.

34. The Organs with which both plants and animals are gifted to enable them to carry on the functions of life, are of two kinds; namely, *simple organs*, such as the flesh of animals, and the cellular tissue of plants; and *compound organs*, such as the leaves of plants, and the limbs of animals—the latter always consisting of certain arrangements or combinations of the former.

35. *The principal substance* of which plants are composed is known by the general name of *tissue;* but of this there are three distinct kinds, distinguished as *cellular,*

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46. Is there any analogy between the decay and death of plants and animals?

47. How are the organs of plants and animals divided?

48. What division is made of vegetable tissues?

woody, and *vascular*, which have been compared to the flesh, bones, and veins of animals. These principal tissues are occasionally subdivided into varieties on account of some minor distinctions, such as vascular tissue, which may be either vascular proper, pitted, or lactiferous.

CELLULAR TISSUE.

36. *Cellular tissue* is the fleshy or succulent part of plants, of which familiar examples may be given in the pulp of leaves and fruits. It consists of a great number of cells of irregular shape, which adhere together, sometimes quite loosely, as in the pulp of an over-ripe orange; and at other times—as, for example, in the cuticle or outer skin—so closely, as to seem to form a homogeneous mass, unless examined by a powerful microscope. Formerly, indeed, it was supposed that an extremely thin membrane was spread over the external surface of some plants; but it is now found that what was supposed an extraneous membrane, is in fact only a more condensed form of cellular tissue.

37. *Each cell* of cellular tissue consists of a small bag or bladder, filled apparently with liquid; but intermixed with this liquid, which consists of hydrogen and oxygen nearly in the same proportions as in water, there are some grains of starch and some of colouring matter, surrounded by a few particles of gluten. The starch, which has been compared to the fat of animals, consists principally of carbon; and the gluten of nitrogen. Occasionally, small crystals are found in the vesicles of cellular tissue, which, when they are needle-shaped, are called *rapides;* sometimes, however, they are of a rhomboid, at other times of a prismatic form. They consist of inorganic matter, generally of some acid and its base, which, from the feeble state of the assimilating powers, have united and crystallized, instead of passing in a separate state through the vessels of the plant, to assimilate with the peculiar secretions. Some cells are entirely filled with these crystals,

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49. Describe the cellular, with examples.
50. What are the nature and contents of these cells?

and others are entirely without them. The cells of the epidermis, instead of liquid, contain only air.

38. *The cells of cellular tissue vary very much both in size and shape.* They generally, however, present the appearance of a honeycomb when sections are cut of the pulp of the leaves, pith, or fruit (see fig. 1); but in sections of the bark and sap-wood, they take a parallelogram form, and resemble the bricks of a wall (see fig. 2). The cells are generally small when they are first formed, but they increase

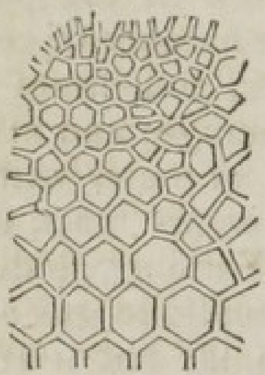

Fig. 1.—Cellular Tissue in a Leaf.

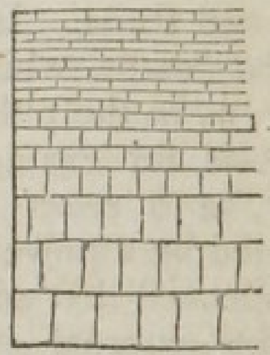

Fig. 2.—Muriform Cellular Tissue in Wood or Bark.

in size as they become older. Thus, in the cellular tissue of a leaf, the cells are at first very small, but as fresh cells are formed close to the veins, the cells towards the margin of the leaf dilate; and a similar process takes place in every part of the plant, the newly formed tissue always consisting of cellules, which enlarge as they get older.

39. *In the pulp of leaves and fruit,* and in the cellular tissue of the bark, there are frequently cavities found among the cells, which are of several kinds. Those called *receptacles of secretion* are formed for the reception of the oils and other fluids secreted by plants; as, for example, the fragrant oil in the myrtle and the orange, and the turpentine in the Pistachia and in the pine and fir tribe. Other similar cavities, called *air cells,* contain oxygen nearly in a pure state; and others, which are called *intercellular passages,* are generally filled with watery fluid, and communi-

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51. Describe the varieties of the tissue.
52. Are there other cavities, and what do they contain?

cates with the open air by means of pores in the epidermis. All these cavities have no distinct membrane to enclose them, but are surrounded by what may be called a wall of small cells, which form part of the cellular tissue. The shape and size of these cavities vary exceedingly; the receptacles of secretion, and the air cells, are generally larger than the common cells, but the intercellular passages in very dry plants are so small as to be scarcely perceptible; though in succulent plants—as, for example, in the stem of the garden Nasturtium—they are nearly as large as the cells.

40. *Cellular tissue readily decays* when the parts composed of it fall from the tree. The carbon it contains is liberated so soon as the vital force by which it was retained has fled, and escapes with the oxygen in the form of carbonic acid gas; whilst the hydrogen, which then forms its principal remaining element, attracts fresh oxygen from the atmosphere, and, becoming thus changed into water, rapidly melts away, leaving the inorganic portion to mix with the soil. In leaves, the pulpy parts disappear first, leaving behind the outer cuticle and the nerves of veins, which are of firmer texture; the latter, indeed, being composed principally of woody fibre, the tubes of which have been filled with earthy matter during the process of vegetation, decay very slowly. A beautiful preparation may be made by soaking, or macerating, as it is called, leaves in shallow stagnant water, so as to leave them perpetually exposed to the influence of the air; thus treated, the cellular tissue will soon disappear, and the veins will present the appearance of the finest lace.

41. *Those parts of a plant which nature seems to have intended not to be of long duration*, such as the fleshy parts of the leaves, the flowers, and the fruit, are composed entirely of cellular tissue of very loose texture. In the stones of fruit, however, which are also composed of cellular tissue, a portion of earthy matter is deposited, which partially

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53. What tissue of plants first decay? Examples.
54. How has nature provided for shorter or longer duration in certain parts of plants, though both alike cellular and perishable?

lines the cells, and gives them a temporary firmness, without destroying their facility of decay; so that the seeds contained in them may be preserved as long as they are kept in a dry state, and yet liberated so soon as they are placed in a situation favourable for germination.

WOODY TISSUE.

42. *Woody tissue* consists of bundles of extremely fine cylindrical cells, tapering at both ends, and of great length

Fig. 3.—Woody Tissue.

and toughness (see fig. 3). The bundles have so much the appearance of fibres, that their true nature was not suspected by the older botanists; and it was supposed that they retained their fibrous appearance even when subjected to the most minute division. It is now found, however, that the fibres of woody tissue cannot be divided beyond a certain point, and that, though they may be made so small as to take seven or eight of them to equal the thickness of a fine hair, each of these exceedingly slender fibres is in fact a hollow tube tapering at both ends, and adhering to other hollow tubes of a similar nature, as shown in fig. 4.

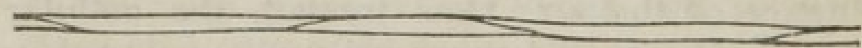

Fig. 4.—Single Fibre of Woody Tissue

The tubes of woody fibre, when young, serve as channels for the passage of the ascending sap; but afterwards they become filled with particles of inorganic matter, which give solidity and durability to the wood. Woody fibre is found mixed with cellular tissue in the wood and inner bark of trees; it also forms part of the veins or nerves of leaves; and in general is found in all organs which require strength,

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55. Describe the woody tissue of plants, and its qualities.

toughness, and durability. It resists decay longer than any other kind of vegetable tissue.

VASCULAR TISSUE.

43. *Vascular tissue* has been divided by modern botanists into three varieties; namely, *vascular proper*, *pitted*, and *lactiferous*. Vascular tissue, properly so called, consists of cylindrical cells of great delicacy and thinness, called *spiral vessels* and *ducts*. *Spiral vessels* consist of hair-like tubes coiled round and round in a spiral manner, and enclosed in tubes of transparent membrane. They are of a light elastic nature, and though coiled up naturally like a cork-screw (see fig. 5), they may be unrolled to a

Fig. 5.—Spiral Vessel.

considerable extent. If a leaf of the spider wort (*Tradescantia*), or of any kind of bulb, be doubled down first on one side, and then on the other, so as to break through the outer skin on both sides, and if the two pieces of the leaf be then carefully and gently drawn asunder, the transparent membrane will break, and the spiral vessels will unrol, so as to appear, when seen with the naked eye, like fine hairs between the two portions of the leaf. The stalk of a strawberry leaf, a shoot of the dogwood, and the young stems and leaves of many other plants, will show the great extent to which their spiral vessels will unrol, if treated in a similar manner; but in many plants these vessels are too fine to be seen without a microscope, or too delicate to bear unrolling. Spiral vessels prevail in leaves and flowers, and are found, though more sparingly, in the young green wood of trees and shrubs; but never in the old solid wood, and very rarely in the roots, or in the bark. They are very few and small in coniferous trees; but they are abundant in palms and their allies. In ferns and the club mosses they

56. How is the vascular tissue divided?
57. What is said of spiral vessels?

occur occasionally; but the other cryptogamous plants are entirely without them. These vessels are sometimes called *air vessels*, because their slender spiral tubes are always found filled with a kind of air, which contains seven or eight times more oxygen than the common air we breathe. ***Ducts*** are cylindrical tubes closely resembling those which enclose the air vessels; only the spiral vessels they contain appear to have been broken into rings, or short corkscrew-like curves, which sometimes cross each other in a reticulated manner. These rings and curves are, however, quite different from the true spiral vessels, as they have no power of unrolling, and appear only intended to keep the slender membrane which forms the duct distended. Similar rings are found in the windpipe of animals, which appear also only intended to keep that membrane distended. The ducts in plants are always found to contain liquid.

44. ***Pitted tissue***, sometimes called *dotted ducts*, or ***vasiform tissue***, consists of tubes which, when held up to the light, appear full of holes, from the numerous dots in the lining of their sides. The mouths of these tubes are very conspicuous in the wood of the rattan when cut across; they are also to be seen in sections of the oak and the vine; and, indeed, in most other kinds of wood, as well as in the stems of herbaceous plants. Being the channels through which the ascending sap is conveyed, the dotted ducts are larger than the vessels of the other tissues, and are distinctly visible in many kinds of wood, even when dry. Modern botanists consider them as belonging to cellular tissue, and as consisting only of elongated cells placed end to end, and opening into each other so as to form a kind of tube. The dots are supposed to be formed by deposition of earthy matter, like that in the cellular tissue which forms the stones of fruits, and which botanists call *sclerogen*.

45. *Lactiferous tissue*, which is the same as the proper vessels of the older botanists, consists of tubes, which are

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58. Describe the spiral ducts.
59. What of the pitted tissue, with examples?
60. What is the nature and use of the lactiferous tissue?

distinguished from all other kinds of tissue by being branched. They are filled with a mucilaginous fluid called the *latex*, which is, in fact, the descending sap, and is full of numerous small specks, like that which is the germ of the future chicken in the egg of a hen. These specks are always in motion while they remain in the vessels of the latex, and whenever they are deposited, they expand into cells of different kinds of tissue. From the latex, also, is formed gum, sugar, tannin, or other secretions, according to the nature of the plant. The vessels of the latex are found on the under sides of leaves, and within the inner bark, which they may be said to line: hence the peculiar secretions of a tree are generally strongest in the bark, and what are not deposited there, are in most cases carried down to the root.

46. *Most kinds of tissue* may be traced in all the compound organs of plants, though in different proportions, except the vessels of the latex, which are only found in the under part of the leaves, and lining the inner surface of the liber, or inner bark.

COMPOUND ORGANS, AND THEIR FUNCTIONS.

47. THE COMPOUND ORGANS OF PLANTS are composed of several of the simple ones; as, for example, a leaf has woody and vascular tissue in its veins, and cellular tissue in its pulpy part; and in like manner, these elementary organs are found in the stem, flower, fruit, and, in fact, in every part of the plant. The compound organs are divided into three kinds; namely, the *general organs*, which are common to every part of a plant, such as the *epidermis*, or skin, and the hairs; *the organs of nutrition*, through which the plant takes and digests its food, such as the root, stem, and leaves; and *the organs of reproduction*, which are the flowers, fruit, and seeds.

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61. How are the compound organs of plants divided?

GENERAL ORGANS, AND THEIR FUNCTIONS.

48. THE EPIDERMIS, OR SKIN, is a thin membrane, which covers every part of a terrestrial plant, except the stigma and the spongioles, but which is sometimes entirely or partly wanting in plants which live under water. It is composed of a kind of cellular tissue; but the cells are pressed so closely together, as to make it appear homogeneous to the naked eye; and they are filled with air instead of water. The use of the epidermis is to retain a sufficiency of moisture in plants; for, should the delicate membrane of which the cells of their tissue are composed become so dry as to lose its elasticity, the different organs would be unable to perform their proper functions. On this account, its thickness is curiously adapted to the conditions under which a plant grows. In ordinary cases, the epidermis consists of two layers, the outer one of which, called the *cuticle*, is extremely thin, and consists of cells of oblong shape and large size, pressed closely together, and filled with air: while the secondary layer is formed of cells of a different shape and size, but still closely pressed together. In the plants of very hot countries, it consists of three, or even four layers, in order that the moisture may be retained, notwithstanding the excessive heat and dryness of the climate. The oleander being a native of a country subject to hot drying winds, has an epidermis which consists of four layers. Those plants which have numerous pores, or stomata, in their epidermis, require watering oftener than others, and are more easily affected by the heat of the sun. Thus, we often see the leaves of the common lilac droop, as though the plant were suffering for want of water; while those of the apple or pear tree which grows beside it are perfectly unaffected by the heat—the latter tree not having above twenty thousand pores in the square inch, while the lilac has one hundred and sixty thousand in the same space. The epidermis of aquatic plants is extremely thin; and, indeed, it is entirely wanting on the under side of floating

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62. Describe the epidermis of plants and its use.
63. What of its layers and pores?

leaves, as also on the stigma of the flower, and on the spongioles of the roots. The cuticle, being composed of cells so firmly pressed together that it is longer in decomposing than any other part, is often found on leaves of which all the pulpy part is decayed. While in a healthy state, the epidermis adheres so closely to the pulpy part of the leaf, that it cannot be separated without laceration of the cells, however easily it may appear to peel off.

49. *The stomata* are valve-like openings in the epidermis, which communicate with the intercellular passages, and which seem intended to regulate evaporation. Sometimes these openings are partially closed with hairs; and succulent and aquatic plants have either no stomata, or have them so imperfectly formed, as scarcely to be capable of action.

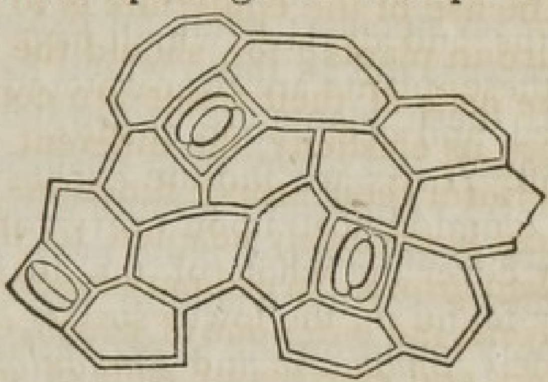

Fig. 6.—Stomata of a Leaf.

They have never been discovered upon roots, nor upon the ribs or veins of leaves. The word *stomata* signifies mouths; and each *stoma*, or mouth, consists of two kidney-shaped cells, which, when open, leave a delicate little slit between them, but which have the power of closing entirely when necessary. The stomata are so extremely small, that one hundred and sixty thousand have been counted in every square inch on the under side of the leaf of the common lilac. They are generally most abundant on the under side of the leaf, and in the lilac there are none on the upper side; but in some plants—for example, in the carnation—the numbers are equal on both sides, and do not amount to more than forty thousand in the square inch in each. In other plants, the numbers are very limited; as, for example, the mezereon has no stomata on the upper side of the leaf, and only four thousand in the square inch on the under. The use of the stomata is to enable the plant to throw off its superfluous water, and

64. What of the stomata or mouths of the epidermis?
65. Their number and peculiarities.

this it does with great rapidity when exposed to the heat of the sun. The vessels of plants are so extremely small, that all the solid substances they take must be reduced to an impalpable form by solution in water before they can be absorbed; thus, a great deal more moisture is taken up by a plant than is wanted for its nourishment; and the superfluous water would distend the vessels, and bring on a kind of dropsy, if it were not evaporated through the stomata. This occasionally happens with plants that have very few or no stomata; such, for example, as the different kinds of cactus, and all those which have succulent or fleshy leaves. If these plants are over-watered, their vessels become diseased, and decay soon ensues.

50. *Hairs* are minute expansions of the epidermis, and are found almost upon every part of a plant. Sometimes they cover the whole of the leaf, and sometimes they are only found on the lower surface. They are of two kinds; namely, *lymphatic* and *glandular*.

51. *Lymphatic hairs* are of various kinds, but they may be divided into short and long. Of the short, the most remarkable are, *down*, or *pubescence*, when the hairs are very short and very soft; *tomentum*, when they are closely pressed to the surface of the epidermis, and appear entangled; *velvet*, when they are very short, dense, and rather rigid; and *bristles*, when they are short, stiff, and wiry. *Hooks* and *barbs* are bristles hooked or barbed at the point. Of the long hairs the principal are those called *hirsute*, which are moderately long and rigid; *pilose*, of the same kind, but longer: *villous*, long and soft; *crinose*, very long and loose; and *silky*, long, but pressed closely to the surface. Besides these kinds, hairs, whether long or short, are said to be *ciliate* when they surround the margin of a leaf or petal, like the lashes of the eye; *bearded* when they grow in erect tufts; and *stellate* when they grow in similar tufts, but are spread out like little stars.

52. *The use of lymphatic hairs* is partly to protect the surface of the leaf from the heat of the sun and from dry-

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66. Describe the hairs of the epidermis.
67. The varieties of hairs, and how designated?

ing winds, and partly to collect moisture from the atmosphere. It is now known that plants take in nourishment from the atmosphere as well as from the ground; and it is supposed that part of this nourishment is absorbed through the lymphatic hairs. It has been observed, that the hairs, when they do not cover the entire surface of the leaf, always grow either upon the veins or in the angles where the veins cross each other. It is thus evident that they have a direct communication with the vessels containing the sap. Lymphatic hairs are most abundant on the under surface of the leaves, which is, indeed, very rarely entirely devoid of them.

53. *Glandular hairs* are hollow, generally open at the point, and with a receptacle of secretion at the base. Of this nature are the stings of the nettle, and the hairs of the sweet-brier, &c., which are filled with a fragrant volatile oil. In both these cases, glandular hairs seem to act as organs of excretion, through which the plant is enabled to exude certain fluids.

54. *The position of hairs* is generally perpendicular to the surface on which they grow; but in some plants they are attached by the middle; as, for example, in all the cabbage tribe.

55. *Scurf* is the name given to a rough and spotted appearance on the leaves of plants, which is also an expansion of the epidermis.

56. *Glands* are organs of secretion, or cells containing liquid different from that in the cells of the common tissue of the plant, as in the flowers of the *Hypericum*, or St. John's wort, which give out a red liquid when pressed. Sometimes glands assume a wart-like appearance; thence the stems or leaves on which they appear are said to be *verrucose*, or *warty;* and sometimes they take the form of little watery blisters, in which case the plant is said to be *papillose.*

57. *Prickles* may be called hardened hairs, as they are merely indurated expansions of the epidermis, without any

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68. What functions do they perform in plants?
69. What other organs are named?

woody fibre; and they may be detached from the branch which bears them without laceration. Occasionally the side veins or lateral ribs of a leaf end in sharp points, which are called *prickles,* as in the leaves of the holly; but these are, in fact, spines, as they are expansions of woody fibre.

58. *Thorns* differ from prickles in being formed partly of woody fibre; and they cannot be detached from the branch which bears them without lacerating its vessels. They are, in fact, abortive, or imperfectly developed buds, and are formed instead of leaves and branches.

59. *Spines* resemble thorns in every respect, except in being found on the leaves and stems of herbaceous plants, while thorns only grow on the trunk and branches of woody plants. When spines grow on leaves, they are always found on the nerves or veins, which are extensions of the woody fibre. Spines serve to protect the leaves; and, in some instances, when the plant has risen above the reach of animals, it produces its leaves without spines.

60. *Of the general organs,* the epidermis is the only one that is sure to be found on every plant, and even of this the cuticle cracks and peels off in the case of old trees. The stomata, it has been already observed, vary exceedingly in numbers, according to the nature of the plant, and in some they are entirely deficient. The hairs are also sometimes wanting, in which case the surface of the leaf is said to be *glabrous,* or smooth.

ORGANS OF NUTRITION—ROOT, STEM, LEAF-BUDS, AND LEAVES.

61. The organs of nutrition are the root, the stem and branches, and the leaves; and of these organs, the root and the leaves, or some modification of them, must exist in every flowering plant, as the vital functions could not be carried on without them.

62. The root is that part of the plant which grows

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70. Define the technicals italicized.
71. What is said of the universality of the epidermis?
72. Name the organs of nutrition.
73. Describe the root.

downwards from the vital knot, or collar, which divides it from the stem.

63. *There are two kinds of roots;* namely, the main root, or *caudex*, and the fibrous roots, or *fibrils.*

64. *The uses of roots* are to give stability to the plant, which is done by the main root; and to supply it with nourishment, which is done by the fibrils.

65. *To give stability to the plant*, the main root either descends to a considerable depth into the ground, or spreads over a sufficient extent of surface, to afford a proper base to the head. When the main root descends perpendicularly, it is called a *tap-root;* and when it divides just below the collar, it is called a *branching root.*

66. *To supply the plant with food from the soil*, the main roots are furnished with a great number of slender fibres, each ending, as the main root does itself, in a soft porous part called a *spongiole*, from its resemblance to a little sponge. This organ imbibes what moisture it can find, and the moisture is thence transmitted through the other parts of the root to the stem and leaves.

67. *Roots elongate* chiefly by fresh tissue forming at the extremity of the fibrils. Thus the spongioles being always the latest formed part of the root, the tissue composing them is looser in its texture than that of the other parts, and more readily absorbs water. The whole root, except the spongioles, is also covered with an epidermis, or skin, which is destitute of pores, and which, in trees and shrubs, become thickened by age into a cortical integument like bark.

68. *A tap-root is always sent down first* by a seedling plant; but as the plant increases in size and strength, the tap-root seems to disappear, as it either changes its form, or is surrounded by other roots, which soon attain such a size and thickness as to render the original root no longer distinguishable.

69. *As plants increase in age their roots enlarge.* Trees and shrubs have, after the first few years, in most cases a

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74. Varieties and uses of roots.
75. What change by age?

branching root, as shown in fig. 7. Herbaceous plants have generally either fibrous roots, that is, a number of roots of the same thickness descending perpendicularly, or extending horizontally from the collar; or they have thickened roots, in which a store of feculent or mucilaginous matter is laid up for the use of the plant, should it be required. Of this nature are the spindle-shaped or fusiform roots of the parsnip (*a* in fig. 8), and the truncated root shown in *b*, the moniliform or granulated root of the meadow saxifrage (fig. 9), fasciculated tubers of the dahlia and peony (fig. 10), and the tuberous roots shown in figs. 11 and 12.


Fig. 7.—Branching Root.

Fig. 8.—Spindle-shaped or Fusiform Root (*a*); Truncated Root (*b*).


Fig. 9.—Moniliform Roots.


Fig. 10.—Fasciculated Root of the Peony.

76. Describe the various roots of herbaceous plants, with examples.

Fig. 11.—Tuberous Roots.

Fig. 12.—Twin Roots.

70. *Roots have no natural buds*, and on this account those roots which produce buds, such as the potato, are generally called underground stems. Some botanists include under this name the fleshy roots of the turnip and carrot; but, as all the buds produced by these roots, and even those found on the tubers of the potato, are always irregular or adventitious (see fig. 13), and as all roots are found occasionally to produce adventitious buds, the mere fact of fleshy roots producing buds does not appear a sufficient reason for calling them stems; particularly where the collar is above the fleshy part of the root, as is decidedly the case with the carrot (see *a* in fig. 14), as all botanists allow that to be the point of division between the ascending and descending axes of the plant, or, in other words, between the stem and the root.

Fig. 13. —Longitudinal Section of a Potato.

Fig. 14.—Section of Fleshy Root, with Collar.

77. What of buds upon roots?

71. *The mode in which plants obtain nourishment from the soil,* is by absorbing the various substances they want in a state of solution. It is well known that a considerable quantity of inorganic matter is taken up by the roots, the particles of which must be in a state of most minute division, and dissolved in many times their own bulk of water, before they can pass through pores so exceedingly minute as those of the spongioles. The same may be said of carbon, which is a solid substance, and which constitutes at least one-half of every vegetable. On this account, the quantity of moisture taken up by every healthy plant is very great in proportion to its size; and it was found, by experiment, that four plants of the common mint, which were grown for fifty-six days with their roots in water, took up during that time seven pints of the fluid, though their own weight was only four hundred and three grains. The fact, that water is imbibed only by the spongioles, has been proved by bending a fleshy root, and placing it in water so as to leave the spongioles dry, when it is said that no water is absorbed, and it is certain that the root withers. If, on the contrary, the fleshy part of the root be kept dry and only the tips of the spongioles immersed in water, the root is maintained in a vigorous and healthy state.

72. *The root elongates much more rapidly than it increases in thickness;* and hence the roots of the largest timber trees are extremely slender in proportion to their trunks. The reason for this seems to be, that a very thick root is not wanted to give stability to a ligneous plant, as it would require an enormous depth of soil to sustain such lofty trunks, were they dependent upon a single root. In tap-rooted trees and herbaceous plants, on the contrary, the main root is as thick as the stem, and sometimes thicker; as in that case the plant is steadied only by the root descending into the ground, and the stem would be apt to be broken off by high winds, if the main root were not of corresponding dimensions. Another reason for the great elongation of the branching roots is, the necessity which

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78. Describe the process of obtaining nutriment from the soil, and its chemical processes.

79. Proportion of growth in the roots of plants.

trees, and other plants intended to last many years, are under of finding fresh soil. This is not felt by annuals, as they cannot in one year exhaust the soil within their reach of all the nutritious substances they may require; and thus even forest trees have generally tap-roots the first year, though their roots afterwards soon become branched.

73. *The construction of roots* differs in many respects from that of stems; though, as in other cases, the characteristic differences appear in some examples to melt so gradually into each other, that it is difficult to draw a distinction between them. It has been before observed, that though plants and animals are really quite distinct, there are some organized forms which it is difficult to class with either, as they appear to belong to both. In like manner, there are some roots that appear to be stems, and some stems that can hardly be distinguished from roots. Of the first kind are the aërial roots sent down by palm and other similar trees, apparently for the purpose of strengthening their stems, which are often very small at the base, in proportion to the height of the tree. The roots sent out by cabbages and cauliflowers from above the collar, when they are transplanted to a rich soil, are of the same kind. Many herbaceous plants send out roots in a similar manner when they are earthed up; and trees which grow in unnatural situations, as on a wall or bare rock, send down roots in quest of soil and moisture, which afterwards take the appearance of stems. The maple, the gooseberry, and some others, may have their roots converted into stems by reversing the plants, and burying the tips of the shoots in the earth, so as to leave the roots in the air. In this case, the branches will soon send out fibrous roots from the joints which have been buried in the earth, and the fibrous part of the old roots withering, the roots themselves will gradually assume the character of branches. With regard to stems being mistaken for roots, the instances are still more common. What are generally called creeping roots, are all underground stems; the rhizoma, or root-stalk, of the water lily, and those of several kinds of ferns, are of a similar nature.

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80. Singular construction of roots.

The tubers of the potato and arrowroot are also called underground stems, which are said to have become so distended and overgrown by an excess of cellular tissue, as to bury the buds and to distort them out of their proper position. This is exemplified in what are called the pine-apple potato, the buds of which are said to be arranged with as much regularity as those of any aërial stem. Bulbs, which were formerly classed with roots, are, in fact, underground stems and distended leaf-buds.

74. *The structure of the woody part of roots* corresponds in a great measure with that of the stem, with the exceptions that no pith exists in roots, and that there are no regular joints, or nodes, for the production of buds. In the place of pith, there is in the centre a bundle of vascular tissue and woody fibre, which is carried on by branches from the main roots through the whole of the fibrous roots, and even through the spongioles; though in the fibrous roots it is only covered by a sheath of transparent cellular tissue, and in the spongioles by tissue of a still softer and looser nature. This bundle of fibre and vessels, forming a kind of cord, may be seen distinctly through the transparent sheath with which it is covered; and as the descending sap is conveyed by it downwards, a portion of that sap, containing the peculiar secretions of the plant, is frequently discharged by it from the roots: hence the ground in which poppies have been grown has been found to contain a portion of opium, and that in which oaks have grown, tannin, &c. On this account, the roots, like the bark, are often found to contain a great portion of the secretions of the plant.

75. *The collar*, or *vital knot*, also called the *collet, neck*, or *crown*, is that part which divides the stem from the root. It is sometimes scarcely perceptible, as in most kinds of herbaceous plants; but in trees and shrubs, it is generally marked by a roughness round the stem, just above the surface of the ground. In the elephant's foot, or Hottentot

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81. What of under-ground stems, bulbs, etc.?
82. Nature and functions of the woody part of roots.
83. What of the collar of plants?

bread, it is exceedingly enlarged, and covered with a hard woody substance (see fig. 15). De Candolle, and other continental botanists, have regarded the collar as the most vital and important part of a plant; and though the majority of modern botanists appear to think that its importance has been overrated, it is quite certain, that if the collar be uninjured, the stem of most plants will grow again when cut down; but no art can make the roots produce another stem where the collar is removed, unless it should be from an adventitious bud. Thus, the tubers of the dahlia, when separated from each other with a portion of the collar attached, will produce separate plants; but if no part of the collar be attached to the separated tuber, though it may continue to live, and even grow, no art can ever make it produce a stem.

Fig. 15.—Elephant's Foot.

76. THE STEM is the ascending axis of the plant, always growing above the collar, as the root grows below it. It is furnished with joints or nodes at regular distances, where the fibres and vessels take a curved direction, so as to form a little recess, plainly discernible when the branch is split in two, in the centre of which the bud is formed that afterwards expands into a branch furnished with leaves, and sometimes producing flowers and fruit.

77. *Stems are either ligneous, herbaceous,* or *suffruticose. Ligneous stems* are those of trees and shrubs, which, being composed principally of woody tissue, are hard and durable. *Herbaceous stems,* on the contrary, being composed chiefly of cellular tissue, are green and succulent, and of short duration, generally dying down to the ground every winter, even when the root survives. *Suffruticose stems* are those which are partly ligneous and partly herbaceous;

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84. Importance of the collar in transplanting.
85. Define the stem and its varieties.
86. Varieties of ligneous stems, and define.

the lower part of the stem being woody, and the young shoots succulent.

78. *Ligneous stems differ in their construction* according as they are Exogenous, Endogenous, or Acrogenous.

79. *Exogenous ligneous stems* increase by successive layers of new wood, deposited within the bark on the outside of the old wood: hence they are called *exogenous*, which signifies to increase on the outside. In external aspect, the ligneous exogens are easily distinguished by the branching and leafy nature of their trunks, which, in the case of forest trees, often present a lofty and commanding appearance (see fig. 16). As shrubs and trees, they yield at once beauty and shelter to the landscape, while their timber, from its strength and durability, is of most essential service to man in the construction of houses, ships, implements, and machinery.

Fig. 16.—Pine.

80. *The stem of a seedling exogenous tree* consists at first only of cellular tissue, surrounded by an epidermis; but as soon as the leaves have expanded, some bundles of woody fibre are deposited, so as to have the appearance of a dotted circle just within the skin. As the tree advances in growth, the cellular tissue in the centre becomes what is called *pith*, and rays of it extend to the epidermis between the bundles of woody fibre. A membrane, or rather layer of vascular tissue, then forms round the pith, so as to separate it entirely from the bundles of woody fibre, and the pith takes the form of a star, with rays diverging from a centre. The pith was called by the older botanists the *medulla*, from the resemblance of its position in the tree to that of the medulla, or spinal marrow of an animal; and for the same reason, the layer of vessels round the central pith is called the *medullary sheath*, and the rays the *medullary rays*. In the second year of a tree's life, the rays and the central pith both contract as fresh layers of woody fibre are deposited, and they

87. Define the technicals here italicised.

continue to do so every year till the tree is full-grown. In the second year's growth of a seedling tree, a complete layer of wood is formed round the pith just within the epidermis, and this is called the *alburnum*, or *sap-wood*. Another layer of vessels, like those in the medullary sheath, afterwards forms round the sap-wood, so that when a second layer of wood is deposited, a distinct ring of vessels remains between the two. This process is continued every year, and, as the layers of vascular tissue have always a different appearance from the tissue of the wood, the rings of vessels between the layers of wood, which are called *concentric circles*, and the medullary rays diminished to fine lines, may be always traced in a section of the trunk of a tree (see *a* in fig. 17). The medullary rays become changed in time into thin hard plates, which still radiate from the centre to the outer circumference of the tree, and which form what is called by the carpenters the *silver grain* of the wood. The central pith, in the meantime, has diminished to a mere speck in the middle of the tree, or, as is frequently the case, it has entirely disappeared. The layer of wood which is deposited every summer, always appears soft and white for the first year; and it is called the *sap-wood*, because the ascending sap rises through it the following spring. This wood is of no value as timber, and carpenters, in their contracts for houses, always agree not to use it, promising, that their wood shall be free from sap, &c. The inner layers of wood in the tree form what is called the *heart-wood*, or *duramen*, which is extremely hard and durable. As the layers of wood are thus distinct, and as one is generally deposited in temperate climates every year, it has been supposed the age of a tree may be found by counting the number of concentric circles; but this rule does not always hold good, for the reasons before explained (par. 32). Sometimes, but rarely, concentric circles are not formed at all; as in the Menispermum, in which, after the first year, the wood appears to be in one mass; as in the trunks of the woody species of Aristolochia, in which

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88. What changes indicate the age.
89. What of the sap-wood in various trees ?

the wood is divided into wedge-shaped portions by the medullary rays; and as in old trunks of Calycanthus, in the wood of which four distinct axes, or central points, may be traced. The sap-wood of regularly-formed wood is always white, but some secretions are conveyed by the returning sap through the medullary rays into the heart-wood, which changes its colour to brown of various shades, dark red, green, or even black, according to the nature of the tree.

81. *The bark of exogenous trees* consists of three, and sometimes four parts; namely, the *cuticle*, or outer skin; the *cortical integument*, or solid part; and the *liber*, or inner bark. Of these, the cuticle, or outer skin, soon cracks, and partially peels off; as from the closeness of its texture, it cannot dilate so as to give space for the bark beneath it, when that organ increases in thickness. The cortical integument is what is properly called *bark*, and this in some trees attains a considerable thickness; as, for example, in the cork-tree, which is a variety of Spanish oak, and in several kinds of elm. This bark, or cortical integument, is occasionally in two layers, the inner one of which increases so rapidly in diameter, that the outer often cracks; and in some trees, as, for example, in the Oriental plane, it falls off in large plates as the part below it expands. The liber, or inner bark, which is quite distinct from the two layers of cortical integument, is very thin, though a layer of it is deposited every year within that of the preceding year. It was supposed by Linnæus that the inner bark became wood the second year, but this is now proved to be incorrect. It is generally very elastic, and dilates as the stem of the tree increases in thickness; but in a few ligneous plants, such as the vine and the honeysuckle, a portion even of the liber is thrown off annually. In the Menispermum and its allies, it is only formed the first year, and then buried in the trunk, where it is found near the pith. In some trees, as, for example, the Lagetto, or lace-bark tree of Jamaica, the liber is capable of extraordinary distension; and in others, as the lime tree, it is remarkable

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90. Describe the varieties of bark, examples.

for its toughness, as is shown in the bast mats which are made of it.

82. *The nodes of exogenous trees and shrubs* are the parts destined to produce buds; and in some shrubs, as, for example, in the vine and the lilac, they are very distinct. They are generally called *joints*, but this is an incorrect mode of speaking, as the stem is not jointed where they occur. When a branch or stem of a ligneous plant is split open, it will be found that at every node there is a peculiar arrangement of the fibres, so as to form a little hollow or cell, in the centre of which the germ of the young bud forms. From some nodes, two buds are produced opposite each other; and in some herbaceous plants, four leaves or flowers spring from each node; but buds are very rarely produced from any other part of the tree, and when they are, they

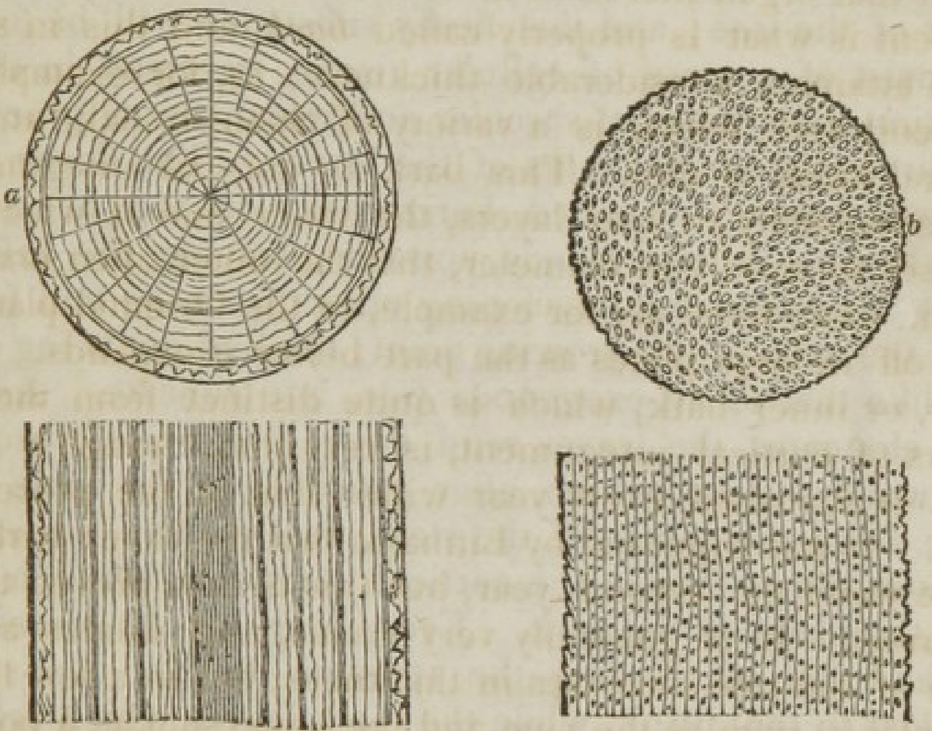

Fig. 17.—Sections of Exogenous and Endogenous Stems.

are said to be adventitious, or irregular. The spaces between the nodes are called *internodes*.

83. *Endogenous ligneous stems* have neither pith, medul-

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91. What are nodes of trees and shrubs?
92. Peculiarities of endogenous ligneous stems.

lary rays, nor concentric circles; and though they have a cortical integument, they have no bark in the proper sense of that word, which signifies a substance easily separable from the wood. A section of the trunk or *stipes* of an endogenous tree (see fig. 17, *b*) consists of a mass of cellular tissue, intermixed with bundles of woody fibre, some of which are deposited every year, the new ones being always inside the others: hence the name of *endogen*, which signifies to increase from within. Nearly all the plants belonging to this division are natives of the tropics, where only a few exogenous trees are to be found.

84. *The trunks of endogenous trees* increase differently from those of exogenous ones. In seedling endogens, a whorl of leaves is first developed, in the centre of which appears a fleshy substance, somewhat resembling the root-plate of a bulb, but of nearly the full size of the after-diameter of the tree; and this fleshy substance will be found to consist of a mass of cellular tissue, traversed in every direction by bundles of vascular and woody tissue proceeding directly from the veins of the leaves. The fleshy part or plate having extended horizontally to the necessary size, begins to rise slowly upwards, leaving the tuft of leaves at its base, but developing others from the bud formed at the apex of the growing point; the bud not being conical, like that of an exogenous tree, but truncate. As the stem elongates, the leaves send down bundles of vascular and woody tissue, which, after proceeding for some distance down the centre of the stem, finally curve outwards, and lose themselves in the cortical integument which supplies the place of the bark. Every year the old leaves decay and fall off, leaving the remains of their foot-stalks attached to the trunk, while the new leaves which are developed send down fresh bundles of fibres in the centre of the stem, and these press the outer ones more closely together, so that the most compact wood is always found nearest the cortical integument of the tree. This cortical integument differs from bark, in being inseparable from

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93. Define the technicals italicised.
94. How do the trunks of this species increase ?

the wood; but it is a mistake to suppose that it will never suffer the tree to increase in thickness, as it is capable of considerable distension, particularly in the dragon trees, and other allied genera. In the palms, however, it soon indurates; and hence these trees, when they have reached maturity, never increase in diameter by age; and as soon as the space within their cortical integument is filled up, they begin to decay. The wood of endogenous trees is much less compact than that of exogenous ones; and, as it is weakest in the centre, it is seldom fit for building purposes. The palms are the principal trees belonging to this division (see fig. 18).


Fig. 18.—Palm.

85. *Acrogenous stems* increase by the *petioles* of the leaves growing together; and thus a section of the wood of the tree fern does not present a series of concentric circles like that of oxogenous trees, nor a fibrous substance like that of the endogens, but a series of zigzag layers, caused by the successive addition of the annual footstalks of the withered leaves. The only trees belonging to this division are the tree ferns (see fig. 19), which are principally found in Van Dieman's Land and New Zealand; but their wood is of no value whatever as timber, and is said to be unfit even for fuel.


Fig. 19.—Tree Fern.

86. *The stems of herbaceous plants* are solid and brittle when young; but when old, they frequently become tough and hollow, in consequence of their diameter increasing more rapidly than cellular tissue can be formed to fill up the space. They differ from the stems of ligneous plants, which are nearly always cylindrical, in be-

95. What of acrogenous stems?
96. Peculiarities of stems in herbaceous plants.

ing sometimes flat, sometimes triangular, and sometimes square. In many cases there is no stem, properly so called; but the flower-stalk rises directly from the root (see *a* in fig. 20), and is then called a *scape*. The stems of the grasses, which are endogenous plants, are hollow, except at the joints or *nodes*, where there is a kind of partition across, so as to divide the hollow part into cells. Stems of this kind are called *culms* (see fig. 20, *b*), and their construction may be seen in the straw of wheat or barley, or the cane of the bamboo. The stems of the maize and the sugar-cane are, however, filled up with fibrous matter, though they also belong to the grass tribe. As the life of herbaceous plants is so much shorter than that of trees, all the functions of their organs are much more rapidly performed. No regular layer of wood is deposited, there are no scales to the buds, and in most cases no buds are formed on the stem for the ensuing year; for the stem itself generally dies down to the ground every winter. In some plants the root dies, as well as the stem, as soon as the seed has ripened, and these plants are called *annuals*, because they must be raised from seed every year. Other plants are called *biennials*, because they seldom flower till the second year, though they frequently live three or four years. ***Perennials*** are those in which, though the stem may die down to the ground, the root remains alive, and is stimulated by the warmth and moisture of spring to send up a growing point, from which fresh leaves, flowers, and fruit, are developed. The stems of evergreen perennials do not die down to the ground in winter.

Fig. 20.—Flower Scape (*a*), and Culm of a kind of Grass (*b*).

87. *The stems of herbaceous and suffruticose plants are of various kinds;* the greater number are erect, but some recline or trail along the ground, when they are said to be *decumbent, procumbent*, or *prostrate*. Sometimes they strike root from every joint, when they are called *creeping stems*

97. What of their period of life?

(see fig. 21); and sometimes they either cling to neighbouring objects by their tendrils, or other means, when they are named *climbers;* or twist their stems round any suitable object, when they are said to be *twiners.* *Runners*, such as are produced by the strawberry, are prostrate stems, forming tufts of leaves and roots at every joint.

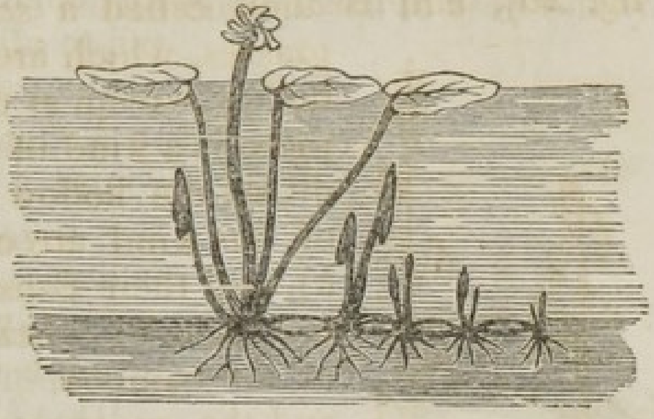

Fig. 21.—An Aquatic Plant extending its Creeping Stems in the Mud.

88. *Underground stems* are those portions of a stem which grow below the surface of the ground. They are generally marked with scales, which appear to be the rudiments of imperfect leaves, in the axils of which buds are formed. Of this nature are the *rhizoma* or root-stalk of the common reed, and that of the water-lily. The *stolones* of the couch grass, and the *tubers* of the potato, are generally considered by botanists to be underground stems.

89. *The succulent stems* of some of the *Cactaceæ* partake of the nature of leaves, of which these plants are generally destitute.

90. Leaf-buds are the means which nature has provided for supplying shrubs and trees with leaves and branches. In autumn, deciduous trees lose their leaves; but in the axil of each (that is, in the angle formed by the footstalk with the branch), a little bud previously forms, from which fresh leaves are to expand the following spring. During winter, the bud is enveloped in numerous imperfect leaves or scales, which are imbricated—that is, laid over one another like the tiles of a house. To this envelope Linnæus applies the term *hybernaculum*, because it serves for the winter protection of the young and tender portions of the bud (see fig. 22). The scales, though generally very thin,

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98. How are the stems of plants diversified?
99. What of leaf-buds?

are of a close membranous texture, well suited to exclude the cold; in many cases they are also covered with a kind of gum. When the particles of the sap become expanded by the heat of spring, the scales open and roll back, or fall off, to allow of the expansion of the true leaves that lie within them, curiously folded up round a kind of stem, called the *axis,* or growing point, which, as the leaves unfold, gradually elongates, and finally becomes a branch.

Fig. 22.—Hybernaculum, or Leaf-Bud.

91. *The outer scales of the leaf-buds vary in different trees.* In the beech and the lime, they are brown, thin, and dry; in the willow and the magnolia, they are downy; and in the horse-chestnut and the balsam poplar, they are covered with a gummy exudation. In some cases there are one or more series of imperfect leaves enclosed within the outer scales of the bud, which drop off when the perfect leaves unfold.

92. *The vernation* of leaves signifies the manner in which they are folded in the bud. The principal forms are the following:—*involute* when the edges of the leaf are rolled inwards spirally on each side, as in the apple; *revolute* when the edges are rolled backwards, as in the rosemary; *convolute* when one leaf is rolled up in another, as in the plum; *conduplicate* when the two sides of each leaf are folded with their faces together, and the midrib projecting, as in the cherry—the compound leaves of the rose are folded in this manner; *plaited* or *plicate* when the lobes of the leaf are each folded separately lengthways, as in the vine; *imbricate* when the leaves slightly overlap each other, like the tiles of a roof; and *valvate* when they just meet without overlapping. There are several other forms, but these are the principal. The vernation of ferns is said to

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100. What change occurs in the winter?
101. Define the technicals italicised on this page.

be *gyrate* or *circinnate*, because the whole stem is coiled up with the leaves, and slowly unrolls when they expand.

93. *The position of leaf-buds*, with regard to each other, is said to be *opposite* when two buds spring from each node, and *alternate* when only one bud springs from a node, as the buds appear first on one side and then on the other. When four or more leaves grow round the stem from the same node, they are said to be *verticillate* or whorled (see fig. 23). Leaves and branches are developed from adventitious buds in the same manner; but these buds rarely appear, unless some injury be done to one of the internodes of the stem.

Fig. 23.—Verticillate Leaves.

94. ***Bulbs*** are at once contracted stems and leaf-buds on a large scale. They are of two kinds: *tunicated*, like the hyacinth; and *scaly*, like the lily. The tunicated bulb is enveloped in a membranous covering resembling the outer scales of a leaf-bud, and enclosing a number of fleshy coatings or tunics, which are undeveloped leaves (see *a*, fig. 24). When the bulb begins to grow, each of these tunics

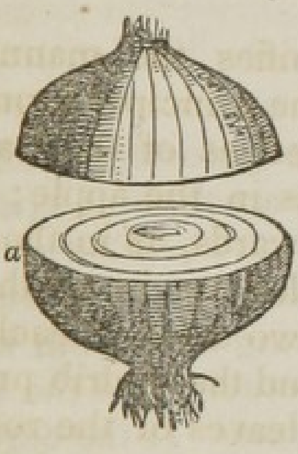

Fig. 24.—Transverse Section of the Onion, a Tunicated Bulb.

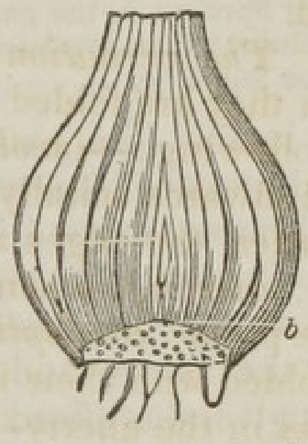

Fig. 25.—Longitudinal Section of the Bulb of a Hyacinth.

forms the base of a leaf, and they all spring from the root-plate (see *b* in fig. 25), which is in itself at once the compressed stem and the collar of the plant. On the upper or

102. Relative position of leaf-buds.
103. Varieties of bulbs.

stem part of this root-plate, new bulbs or offsets are formed every year, exactly as leaf-buds are on the stems and branches of shrubs and trees. Besides these offsets or young plants, another bud, or a new bulb, is formed every year on the root-plate (see fig. 26), to supply the place of the old one, which has wasted away in the course of the growing season, the substance of its tunics having been exhausted in supplying nourishment to the leaves which sprang from them. The scaly bulb (fig. 27) still more plainly

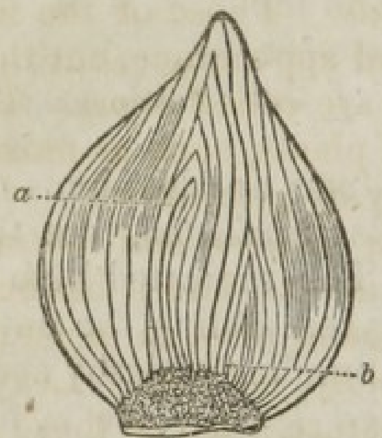

Fig. 26.—Section of a Tulip Bulb in Autumn: *a*, the Flower of the following Spring; *b*, the germ of the new Bulb, which is perfected during the Summer.

Fig. 27.—A Scaly Bulb.

shows its bud-like nature. The loose scales are evidently the rudiments of leaves growing round a common axis, and the offsets are formed in their axils.

95. *Corms*, formerly called *solid bulbs* or *bulb-tubers*, are, in fact, short distended stems, bearing buds from which spring the leaves and flowers. The crocus and the corn-flag or gladiolus afford examples of corms. If the corm of a crocus be cut in two, just before the leaves begin to appear, it will be found to consist of a collar, from which the long slender true roots spring; a solid white part, which is the stem; and one or two little buds in the upper part, which contain the germs of the future leaves and flower. A new corm forms every year to supply the place of that which wastes away when it has done flowering. In the

104. What of scales, corms, etc.?

crocus, the new corm forms above the old one, which wastes away, leaving its dry outer skin like a fibrous ring at the base of the new corm which is to supply its place.

96. Leaves, when perfect and fully developed in flowering plants, consist of two parts: the *lamina, limb, blade,* or disk, and the *petiole,* or footstalk; the latter, in many cases, being articulated or jointed with the branch or stem, so as to be readily detached without laceration when the leaf begins to decay. Sometimes the footstalk is wanting, in which case the leaf is said to be *sessile.* The leaves of cryptogamous plants are called *fronds.* Those of the fern resemble other leaves in their general appearance, but their veins are zig-zag, and their petioles are called *stipes.* The *frond* or *thallus* of the lower tribe of plants, such as mosses and lichens, is always either leathery or gelatinous.

97. *Trees which lose their leaves in autumn, and continue bare during winter,* are said to be *deciduous;* and it has been observed, that those leaves which abound most in moisture, and of course evaporate it most rapidly, fall first. Leaves which are of a thin membranous nature, such as those of the beech and hornbeam, often retain their hold, though withered, till spring. Some trees retain their old leaves unwithered, till after the new leaves have expanded, such as the holly; and these are called *evergreens,* because they never appear divested of leaves.

98. *The blade of every leaf* consists of a *skeleton* or framework, with its interstices filled up by a pulpy matter formed of cellular tissue, or *parenchyma,* the whole being covered by an *epidermis.*

99. *The structure of the blade* of a leaf is both curious and beautiful. The upper and under surface are frequently different both in colour and texture, and are, in fact, perfectly distinct, forming two strata, laid one upon the other, and adhering together. In most cases the adhesion is so close that the leaf appears only one mass; but in some kinds of Indian plants, the two surfaces of the leaves adhere so slightly, except at the margin, that the hand may be

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105. Analysis of leaves.
106. What of deciduous trees?

passed between them, as though it were put into a stocking.

100. *The skeleton or framework of every leaf* consists of two distinct strata of veins, one of which conveys the sap to the upper part of the leaf, and the other to the under. In a species of oxalis or wood-sorrel, introduced in 1841 from Guatemala, the texture of the plant is so transparent as to show distinctly the arrangement which nature has provided for feeding the leaves with sap from the root. This plant has three leaflets, and the leaf stalk contains, in its central bundle of fibres, six sets of vessels, arranged in pairs, so that each leaflet has two distinct sets of tubes communicating with the tree. When the leaf has fully expanded, a set of the branching vessels of the latex will be found on the under side, which are destined to convey the descending sap, after it has been formed in the leaves, back into the tree. The veins of the upper surface are sunk beneath the level of the cellular tissue, and those of the lower surface project beyond it. The veins of the lower surface are usually covered with hairs, while those of the upper surface are smooth.

101. *The venation*, or arrangement of the veins, differs in

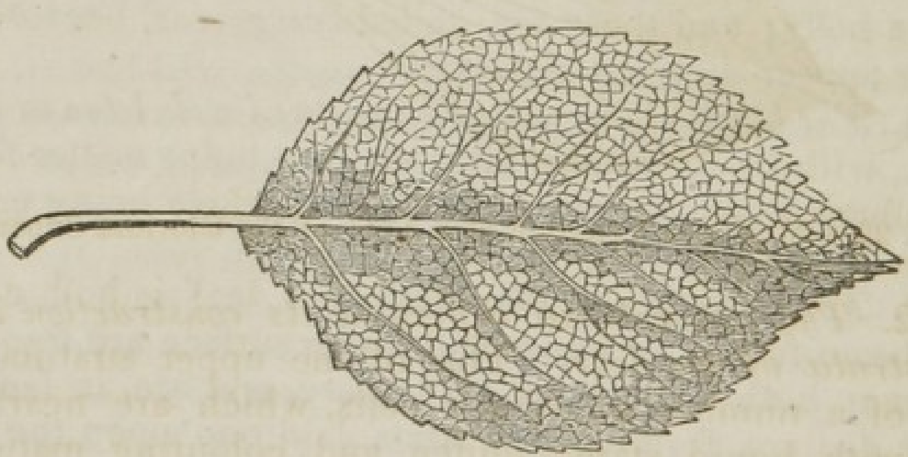

Fig. 28.—Reticulated Venation of a Leaf of an Apple-tree.

different plants; but in nearly all there is a strong vein down the middle, which is called the *midrib*, and is a continuation of the petiole. Sometimes there is no other rib than

107. Describe the blade of leaves, in structure, framework and venation.

this, as in the leaves of the carnation; but in most exogenous plants there are side ribs, called the *lateral nerves*, which branch out on both sides. When these are very conspicuous, the leaf is said to be *feather-nerved*, as in the beech. In some plants, as Melastoma, the auxiliary ribs are not feathered, but lie parallel or nearly so to the midrib. In the leaves of the greater number of exogenous plants, however, the side ribs are less distinctly marked than the midrib, and the space between them is filled up with a network of minute veins, as in the leaf of the apple (see fig. 28). Leaves of this kind are said to be *reticulated*. In the leaves of endogenous plants there are either only a number of parallel veins, with some larger than the others, or there is a central rib, with minute nerves arranged beside it in a *muriform* manner (see fig. 29).

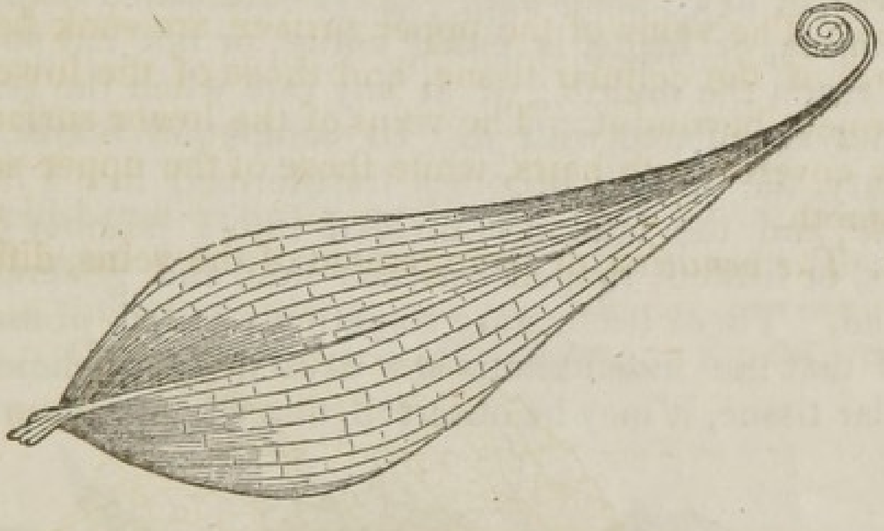

Fig. 29.—Muriform Venation of a Leaf of the Gloriosa Superba.

102. *The parenchyma differs in its construction in the two strata of the leaf.* That of the upper stratum consists of a number of oblong cells, which are nearly all filled with liquid, starch, gluten, and colouring matter, or *chlorophyll*. It is generally destitute of air-cells or intercellular passages, but occasionally contains receptacles of secretion. The parenchyma of the lower stratum, for the most part, appears of a paler colour, as its cells hang loosely

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108. Peculiarities of the ribs of leaves.
109. What of the parenchyma?

together, and abound in air-cells and intercellular passages. The veins of the lower stratum are furnished with hairs. which appear to act like the spongioles of the roots in absorbing nourishment; only deriving it from the air instead of from the ground. The epidermis of the lower stratum has generally more stomata than that of the upper, through which a considerable transpiration of water is always taking place. Notwithstanding the difference that commonly exists between the two strata of the leaf-blade, in some cases both are alike, as in the Eucalypti, the leaves of which hang so curiously as not to present one surface more than the other to the perpendicular light. In other plants, as the water-lily, the strata appear to be reversed.

103. *The parenchyma of the leaf is sometimes deficient in quantity;* when this is the case, leaves are said to be *cut*, or *lobed*, or to be *compound*. Leaves are called *simple* when the lamina, or blade, is either entire, or not cut so deeply as to reach the midrib; or at any rate when the segments are not articulated with it. In compound leaves, on the contrary, the midrib becomes transformed into a kind of petiole, and the lamina is divided into a number of little leaves, or leaflets, ranged on each side, and generally articulated. These leaflets are sometimes called *pinnæ*. As proof that the indentations are caused by a deficiency of cellular tissue, it may be observed, that when trees or shrubs

Fig. 30.—Cordate (*a*), Reniform (*b*), and Tongue-shaped (*c*) Leaves.

with notched leaves are planted in rich soil, or supplied abundantly with water, their leaves become entire. If simi-

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110. What of deficiency in cellular tissue?

larly treated, even trees with compound leaves will produce simple entire ones. In some plants, the parenchyma is entirely wanting, and the framework of the leaf takes the form of a tuft of prickles. This is especially the case with the cactus tribe, the greater number of which have no leaves, but only fleshy stems and prickles.

104. *Simple leaves* are of various forms; as, for example, some are *cordate*, or heart-shaped (fig. 30. *a*), as in the major convolvulus; *reniform*, or kidney-shaped (*b*), as in the ground ivy; or *tongue-shaped* (*c*), as in some kinds of me-

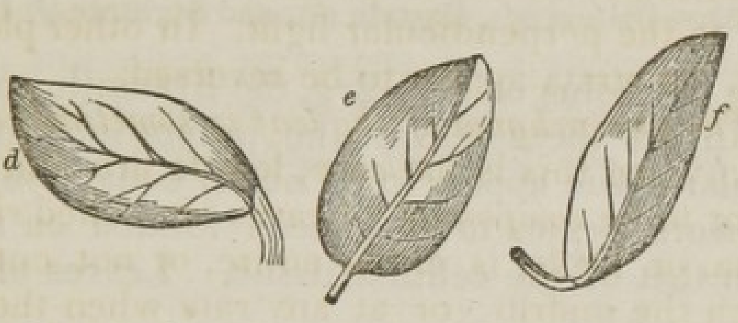

Fig. 31.—Oval (*d*), Ovate (*e*), and Elliptic (*f*) Leaves.

sembryanthemums or fig marigolds. Others are *oval* (*d*, in fig. 31), *ovate* (*e*), *elliptic* (*f*); but these shapes, which are found in numerous plants, are too obvious to require examples. Other leaves are *lanceolate* (*g*, fig. 32,) that is,

Fig. 32.—Lanceolate (*g*), Ensiform (*i*), and Spathulate (*h*) Leaves.

tapering at both ends, as in the mezereon and the common plantain; or *spathulate* (*h*), as in the field daisy. The

111. How are simple leaves diversified in form?

leaves of bulbous plants are generally *ligulate*, or strap-shaped; *ensiform*, or sword-shaped (*i*), as in the iris or flag

Fig. 33.—Deltoid (*j*), Hastate (*k*), and Sagittate (*l*) Leaves.

flower, the gladiolus or corn-flag, the hyacinth, and the narcissus. In all these leaves the proportions of cellular and vascular tissue appear to be nearly equal; but in others the framework seems to have been formed on a different scale from that of the cellular tissue. Leaves of the latter

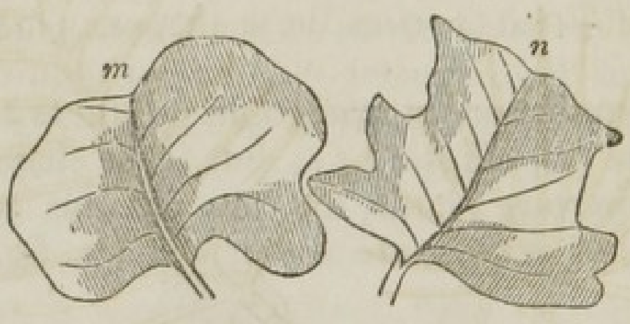

Fig. 34.—Retuse (*m*) and Truncate (*n*) Leaves.

kind are often oddly shaped. Some are called *deltoid* (*j* in fig. 33), from a supposed resemblance to the Greek letter Delta; others are *hastate*, or halbert-shaped (*k*), as in

Fig. 35.—Needle-shaped (*o*) and Subulate (*p*) Leaves.

the common arum; *sagittate*, or arrow-shaped (*l*), as in the sheep's sorrel and pond arrow-head; *retuse* (fig. 34, *m*), as

112. Varieties of leaves, and names.

in the bilberry or whortleberry; and *truncate* (*n*), as in the tulip-tree. The leaves of pines and firs are generally nar-

Fig. 36.—Scimitar-shaped (*q*) and Hatchet (*r*) Leaves.

row in proportion to their length, are of equal width throughout, and often terminate in a sharp point, with a projecting whitish line down the back, which is the midrib. These leaves are called *linear* (*o* in fig. 35); and those of

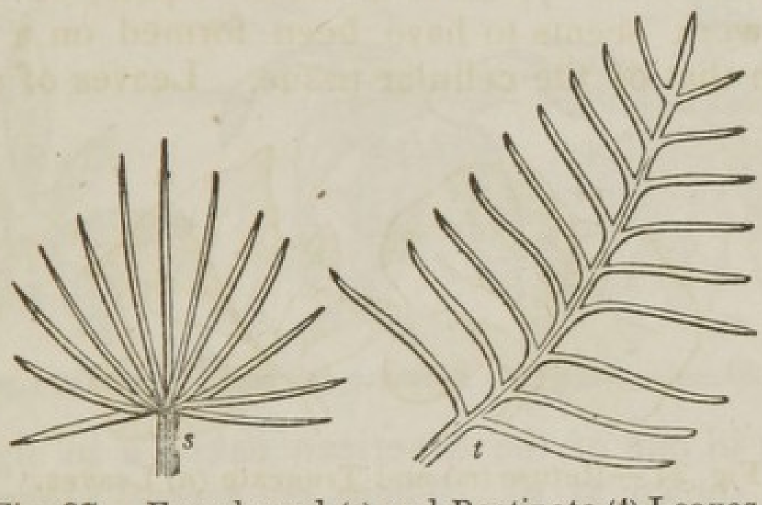

Fig. 37.—Fan-shaped (*s*) and Pectinate (*t*) Leaves.

some other plants, such as the common furze or whin, which are cylindrical and tapered off to a point, like a cobbler's awl, are called *subulate* (*p*). The leaves of the mesembryanthemums, which are thick and fleshy, are often of very odd forms—as, for example, *deltoid* (*j* in fig. 33), *scimitar-shaped* (*q* in fig. 36), or *hatchet-shaped* (*r*). In other simple leaves, the framework seems to have been formed on a scale so much too large for the cellular tissue, that the midrib and principal veins are barely covered, as in the *flabellate* or fan-shaped leaf (*s* in fig. 37), and the *pectinate* or comb-shaped leaf of the water milfoil (*t*). When

113. Define the technicals italicised.

plants with leaves of this kind are removed to a rich moist soil and warm situation, their bare ribs become covered with

Fig. 38.—Lyrate (*u*) and Lobed (*v*) Leaves.

flesh—the pectinate leaf is changed into what is called *pinnatifid*, and the fan-shaped become *lobed*. Some leaves are naturally *pinnatifid*, as in the common fern (*Polypodium*);

Fig. 39.—Digitate (*w*), Palmate (*x*) and Pedate (*y*) Leaves.

lyrate, as in one of the American oaks (*u* in fig. 38); or *lobed* (as shown at *v*). There are several kinds of lobed leaves; as, for example, three-lobed, like the hepatica, and five-lobed, as the vine. *Digitate* leaves, like those of

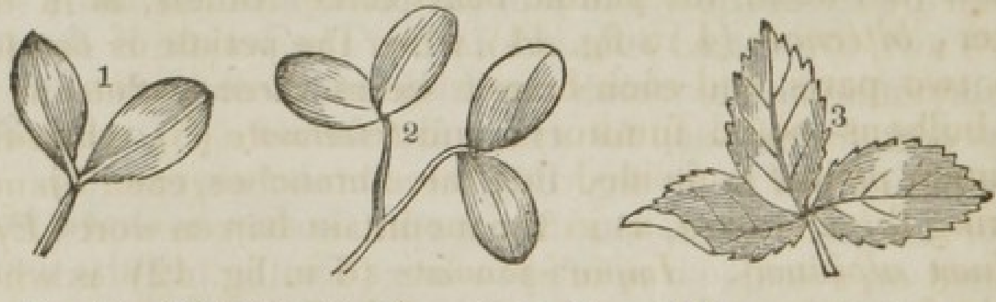

Fig. 40.—Bifoliate (1), Bigeminate (2), and Ternate (3) Leaves.

the horse chestnut (*w* in fig. 39); *palmate* leaves, like those of the passion flower (*x*), and *pedate* leaves, like those of the Christmas rose and of the dragon arum (*y*), are also regarded as simple, though they appear compound from their deficiency of cellular tissue.

105. *Compound leaves* are also of many different forms. *Bifoliate* (1 in fig. 40), when the petiole of the leaf bears two leaflets, as in the bean caper; *bigeminate* (2), when the petiole of the leaf divides into two, and each branch bears a pair of leaflets, as in the cat's claw, primosa; and

Fig. 41.—Biternate (4) and Triternate (5) Leaves.

Fig. 42.—Impari-pinnate (6), Abruptly Pinnate (7), and Cirrhosely Pinnate (8).

ternate (3), when the petiole bears three leaflets, as in the clover, *biternate* (4 in fig. 41), when the petiole is divided into two parts, and each branch bears three leaflets, as in the bulbous-rooted fumitory; and *triternate* (5), when the common petiole is divided into three branches, each branch bearing three leaflets, as in the mountain barren wort (*Epimedium alpinum*). *Impari-pinnate* (6 in fig. 42) is when the leaf consists of several pairs of leaflets, terminating in an odd one, as in the mountain ash; *abruptly pinnate* (7),

114. What of compound leaves and their diversities?
115. Varieties of compound leaves and names.

when there is neither terminal leaflet nor tendril, as in the orobus tuberosus; and *cirrhosely pinnate* (8), when the pinnate leaf terminates in a tendril, as in the common pea. ***Digitately pinnate*** (9 in fig. 43), and *conjugately pinnate*

Fig. 43.—Digitately Pinnate (9) and Conjugately Pinnate (10).

Fig. 44.—Decursively Pinnate (11) and Interruptedly Pinnate (12).

Fig. 45.—Bipinnate (13) and Tripinnate (14).

(10), are rather rare forms of compound leaves, and only occur when the petiole of the pinnate leaf is a branch from a common petiole. ***Decursively pinnate*** (11 in fig. 44) is

116. Define the technicals.

when the petiole of the pinnate leaf is winged by the elongation of the leaflets at the base, as in the melionthus or honey flower, sometimes called Sicilian ragwort. This form of leaf is not very common, and when it does occur, it is difficult to distinguish it from the pinnatifid. *Interruptedly pinnate* (12) is when the leaflets are alternately large and small, as in the potato; and *bipinnate* and *tripin-*

Fig. 46.—Sinuated (15) and Repand (16) Leaves.

Fig. 47.—Crisped (17) and Undulated (18) Leaves.

Fig. 48.—Runcinate (19) and Ciliated (20) Leaves.

nate when they are twice or thrice pinnate, as represented in 13 and 14 (fig. 45).

106. *The margins* of leaves are also variously formed. They are said to be *entire* when they present one unbroken outline; *sinuated* (15 in fig. 46), like the oak; *repand* (16); *crisped* or curled (17 in fig. 47); *undulated* or waved (18); *runcinate*, as in the dandelion (19 in fig. 48); *ciliated* or fringed like the lashes of the eye (20); *plaited* or folded

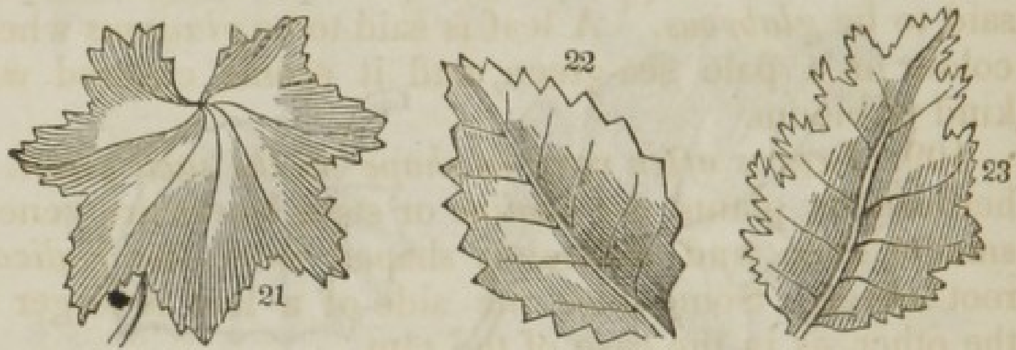

Fig. 49.—Plaited (21), Dentate (22), and Bidentate (23) Leaves.

(21 in fig. 49); *dentate* or toothed (22), and *bidentate* (23); *serrated* or sawlike (24 in fig. 50); *crenated* or scolloped

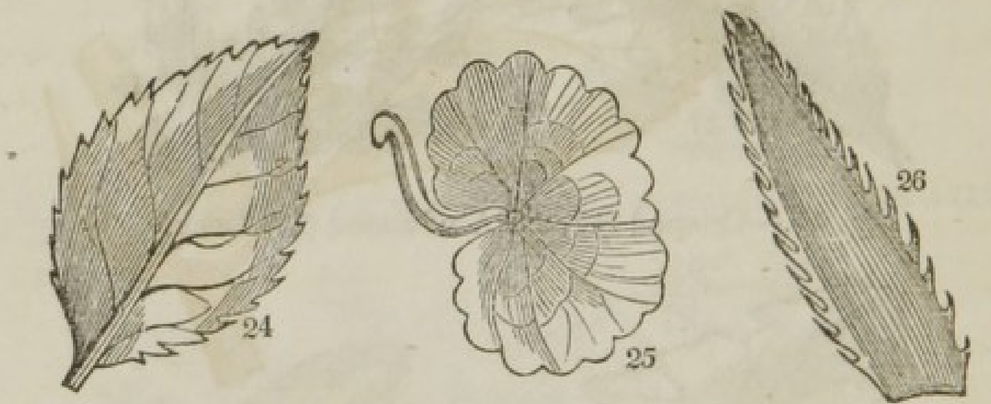

Fig. 50.—Serrated (24), Crenated (25), and Armed (26) Leaves.

(25); and *armed* (26). To these may be added *erose* or gnawed, when the margin appears as if it had been bitten by some animal; *lacinated* or deeply and irregularly cut, and *incised* or regularly cut.

107. *The apex or termination of a leaf* assumes various forms. When drawn out to a long point, the leaf is said to

117. How are the margins of leaves?
118. Marginal variations and names.
119. What of the apex and surface of leaves?

be *acuminate;* when notched in the middle (as in fig. 34, *m*), *emarginate;* when tapering abruptly to a point, *cuspidate;* and when ending in a little bristle, *mucronate.* Sometimes the apex extends in the form of a tendril, as in *Gloriosa superba* (fig. 29 in page 53).

108. *The surface of leaves* is generally covered with hairs, scurf, blisters, or prickles; when smooth, leaves are said to be *glabrous.* A leaf is said to be *glaucous* when its colour is a pale sea-green, and it seems covered with a kind of bloom.

109. *Leaves often vary in shape on the same plant.* In herbaceous plants the *cauline* or stem leaves are generally smaller than, and differently shaped from, the *radical* or root leaves. Sometimes one side of a leaf is larger than the other, as in the case of the elm.

Fig. 51.—Stipules.

110. *Stipules* (see *a* in fig. 51) are leaf-like bodies formed at the base of the petioles of the true leaves, and generally sheathing the stem. When they are membranous, and joined together, so as to form a sheath entirely round the stem, as in the tart rhubarb, they are called *ocreæ*, or *boots.*

111. *The petiole* of a leaf often changes its form consi-

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120. Varieties in same plant.
121. What of stipules and petioles?

derably. When the leaf is wanting, it is generally either dilated into a leaf-like body termed a *phyllodium*, or drawn out into a long slender filament called a tendril (see fig. 52). Sometimes these tendrils are metamorphosed branches,

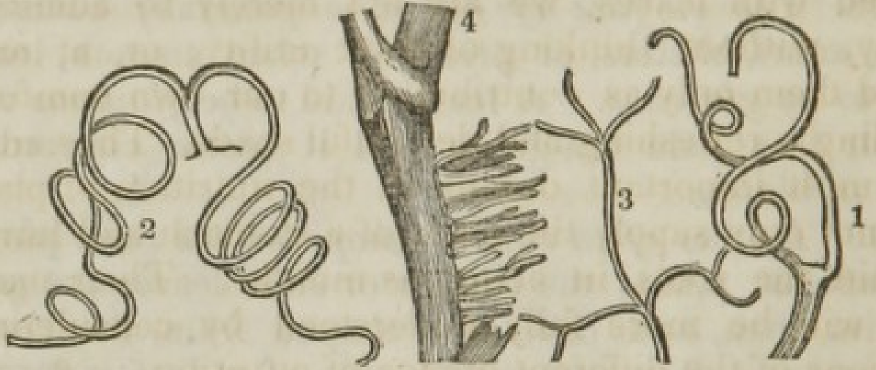

Fig. 52.—Tendrils of the Grape Vine (1), of the Pea (2), of the Clematis Cirrhosa (3), and of the Ivy (4).

as in the grape vine (see 1 in fig. 52); in other cases they are abortive leaves, as in the pea (2); or metamorphosed bracts, as in one of the kinds of clematis (3). In the ivy, the tendrils take the shape of roots (4), and it has been supposed that they bury themselves in the trees to which they are attached; but the fact is, that the ivy is a creeping plant, and uses its tendrils merely to take hold of the objects to which it attaches itself. In a few cases, the petiole is both dilated and drawn out, though the leaf is not wanting, as in the Chinese pitcher-plant (see fig. 53), in which

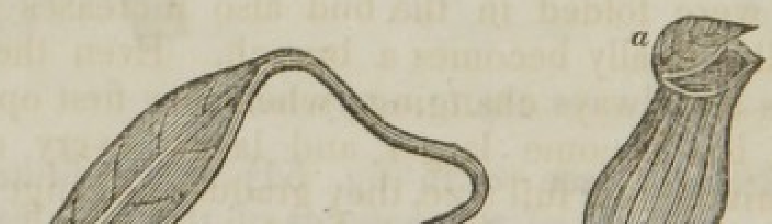

Fig. 53.—A Leaf of Nepenthes Distillatoria.

the lid of the *ascidium*, or pitcher (*a*), is the true leaf, and all the rest the dilated petiole. The same kind of formation is seen in Venus's fly-trap, the true leaf of which consists only of the small lobes which form the trap.

112. *Many other forms of leaves and their appendages* might be enumerated, but those already given will be sufficient to show the wonderful variety which has been displayed in these beautiful objects. When we look at a tree covered with leaves, we are apt merely to admire their beauty, without thinking of their utility; or, at most, to regard them only as contributing to our own comfort, and affording a refreshing and delightful shade. They are, however, most important organs in the nutrition of plants, as they not only supply the place of a stomach and lungs, but also aid the roots in acting as mouths. Their use, however, will be more fully understood by considering the functions of the different organs of nutrition.

FUNCTIONS OF THE ORGANS OF NUTRITION.

113. The organs of nutrition are essential to the existence of vegetation; as all plants, while in a growing state, require to be regularly supplied with food, to afford matter for their increase and for the other changes which are continually taking place within them during the whole of that season. Early in spring the buds begin to swell and to increase in size; and as soon as they expand into leaves, new buds are formed in their axils, which are continually enlarging, till they in their turn, the following spring, give birth to another race of leaves. The axis round which the leaves were folded in the bud also increases as they expand, till it finally becomes a branch. Even the leaves themselves are always changing; when they first open they are small, but become larger and larger every day, till having attained their full size, they gradually change colour, wither, and fall, leaving buds behind them containing the leaves which are to supply their place the following year. Stems also increase every year in height and thickness, till the period comes for their decay; and even then they do not remain in a permanent state, for chemical changes take place within them, by which they moulder away, and the

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122. Functions of leaves.
123. What of the process of nutrition ?

elements which composed them are set free to combine again, and to form a new race of vegetables.

114. *The food of plants* consists partly of the four elementary substances which are found to constitute the organic or living part of all vegetables, and partly of those inorganic matters which are deposited in different proportions in different plants, without being thoroughly assimilated with their substance. The four elements consist of one solid substance, namely, carbon, and three gases—oxygen, hydrogen, and nitrogen. Of these, carbon is by far the most important, as it forms nearly half of every vegetable; oxygen is next, then hydrogen, and lastly, nitrogen, of which the proportion is not more than two and a half or three per cent., but small as this quantity is, it is essential: in fact, no plant can long remain in a vigorous state if it be not regularly supplied with food containing all these four elements. A certain amount of inorganic matter, derived from the soil, is also taken up by the roots through the medium of water; and these substances, though more abundant in some kinds of plants than in others, are also indispensable to perfect vegetation. They are easily detected by burning, as they are not destroyed by the action of fire; and thus, when a rick of hay is burned, a small quantity of flinty matter is found to remain, which is, in fact, the silex absorbed by the plants of which the hay was made, while they were in a living state. The proportion of inorganic matters found in plants is very small; the greatest being about ten per cent., as in the straw of wheat and barley, and other grasses; and the least not exceeding four or even two parts in a thousand, as in the oak and some other forest-trees.

115. *The organic food* of plants consists of carbonic acid gas, water, and nitrogen, the last being generally in the form of ammonia. The carbonic acid gas is obtained partly from decaying vegetable matter in the soil, and partly from the atmosphere. In the former case, the carbon of the soil attracts oxygen from the atmosphere, and the gas so formed,

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124. Describe the food of plants.
125. What of organic food?

being dissolved in water, is absorbed by the spongioles of the root; in the latter, the carbonic acid is derived directly from the atmosphere, and absorbed through the leaves. The water, which yields both oxygen and hydrogen, is obtained chiefly from the soil, but it also enters by the leaves; and the ammonia is absorbed from manure and decaying animal substances, though part of it appears also to be obtained from the atmosphere. Thus, all the elements which form the organic part of plants may be obtained from the atmosphere without any aid from the soil, and probably are so occasionally; though only carbonic acid gas seems in ordinary cases to be habitually derived from that source.

116. *The inorganic matters* taken up by plants are derived entirely from the soil, and must be dissolved in water before they can be absorbed. They consist of the primitive earths, various kinds of salts, and a few minerals. The salts are composed of some kind of acid, and a base with which it can combine; the bases most common in the vegetable kingdom being the three alkalies—potash, soda, and ammonia. Of these, potash is by far the most abundant; and it is indeed so common in almost every plant, that their ashes are used for making ley, a substance composed principally of potash, and used in washing coarse linen. The leaves generally produce more potash than the wood, from the quantity which is lodged in the tubes of woody fibre in their veins. Nitre or saltpetre is a neutral salt, formed by the combination of nitric acid with potash, which has a powerful effect on vegetation. Soda is found abundantly in plants growing near the sea, and it is frequently obtained by burning sea-weed. Ammonia is found in all animal manures, and, combined with the different acids, it forms various salts, which, however, are not so common in plants as the salts of potash and soda. All animal and vegetable substances containing nitrogen evolve ammonia in its volatile state during decomposition. The primitive earths are found in plants either in a pure state, or combined with carbonic, sulphuric, muriatic, or phosphoric acids. Albumen and gluten, which compose the principal substance of

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126. What of the inorganic food of plants?

seeds, always contain a small portion of some kind of phosphate; such as phosphate of lime or phosphate of magnesia. The oxides of iron and manganese are also found in many plants; the latter more rarely, and in less abundance, than the former. Inorganic matters are thus necessary to the development of every perfect vegetable, some species requiring them more largely than others; hence the importance of supplying cultivated soils with those substances, in the form of stimulants and manures.

117. *The absorption of the food of plants* takes place partly through the spongioles of the roots, and partly through the lymphatic hairs of the leaves. All the substances taken up by the roots are mixed with a very large proportion of water, as otherwise they could not pass through the minute passages by which they are conveyed into every part of the plant; but the food absorbed by the leaves appears to be in a more concentrated state, though it also must be either in a liquid or gaseous form. The liquid taken up by the roots is known, as soon as it enters the plant, by the name of *sap;* as is also that imbibed by the leaves.

118. *The assimilation of the food* is a chemical operation, but it differs from ordinary chemical combinations in life being the principal agent. It is called *organic chemistry*, because performed by the organs of living beings. Thus, though a chemist may ascertain that seeds are composed of carbon, with a small proportion of nitrogen, and that wood consists principally of woody fibre, composed of carbon, oxygen, and hydrogen, the tubes of which have been filled up with some kind of inorganic matter, it is not in his power to make either seeds or wood by chemically combining the elements of which they are composed, because life, the principal agent, is wanting.

119. *The sap of plants* is of two kinds; the *ascending sap*, or *lymph*, which rises in spring and early summer, and which consists principally of the liquid taken up by the roots; and the *descending sap*, or *proper juice*, which flows

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127. Name the varieties of earths and metals, etc.
128. What of the absorption by plants?
129. What is remarkable in the assimilation?

downwards in the latter part of summer and autumn, and which appears to consist principally of the sap absorbed by the leaves.

120. *The ascending sap and the descending sap* are quite different both in their appearance and qualities. The ascending sap is thin and watery, and somewhat sweet; but it contains no noxious properties, even in the most poisonous plants. The natives of the Canary Islands tear the bark off a poisonous kind of Euphorbia, which grows wild in that country, and find the ascending sap which they obtain from the alburnum a refreshing drink; though the descending sap of the same tree is of so acrid a nature as to act as a caustic, and to burn the flesh of those who may happen to touch it. The ascending sap of the maple and some other trees is sufficiently sweet to make sugar by evaporation; but the descending sap of the same trees does not possess any sweetness.

121. *The sap begins to ascend in spring*, and continues to rise till the leaves are fully developed, and begin to imbibe nourishment from the air. The principal current of the sap then descends by the vessels of the latex, and continues to do so for some time, as the ascending sap had risen, but not with equal rapidity. The force with which the sap ascends is so great, that a bladder tied over the stump of a vine, from which a piece had been cut off early in May, was torn into shreds by the rising of the sap; and by the experiments of some French and German botanists, it is found that the motion of the sap is generally five times greater than that which impels the blood in the principal artery of the horse.

122. *The sap ascends principally through the large dotted ducts in the alburnum*, but partly also by the tubes of the woody fibre, as may be seen by cutting across the branch of a vine in spring, when the sap will be seen oozing out of the mouths of the vessels in large globules from the dotted ducts, and in very small ones from the hollow tubes of

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130. Describe the varieties of sap?
131. What of the circulation of the sap?
132. Changes and uses of the sap.

the woody fibre. The ascending sap of all plants is nearly the same; if drawn from the tree just above the collar, it looks and tastes like water, but if drawn from a higher part of the trunk, it appears thick and yellowish, like weak gum water, and tastes of mucilage and sugar. This change is produced by the ascending sap mixing with certain portions of starch (changed into sugar) and gum, which were deposited by the descending sap the previous season.

123. *The lymph or ascending sap* always flows through the soft or sap-wood, and it spreads horizontally as well as rises vertically. It furnishes the cellular tissue for the leaves, stem, and bark, and deposits the earthy matter carried up with it in the woody fibres of the heart-wood, which when these are filled up, becomes dead, and undergoes no further change till it begins to decay. The sap only continues its rapid ascent till the leaves are fully developed, and then, though it continues to ascend, it is with little force, as the principal current of the sap is downwards. The change in the principal current of the sap generally takes place in trees about midsummer, or at any rate before the month of August. In herbaceous plants, it takes place at an earlier period, as the life of the plant is so much shorter; and wherever the summer is hot and short, the sap descends sooner than in countries where the summer is longer and more temperate.

124. *The proper juice or descending sap* always takes its principal current through the bark, though it also spreads horizontally as well as vertically. It contains all the peculiar products of the plants, such as milk, oil, and resin, which it deposits as it descends. It also deposits mucus, to form the first layer of *liber* or inner bark, within the epidermis, which, by similar deposits, becomes changed into the outer bark; and other mucus for the formation of woody fibre and those tissues of which a new layer of wood is composed. It then passes downward to the roots, which it hardens by its various deposits, and to the tip of which it sends matter for fresh cellular tissue, to form new spongioles, while the epidermis creeps over those that formerly existed.

125. *It was at one time supposed* that the lymph changed to proper juice in the leaves, only by throwing off its superfluous air and moisture, and that this was done by light decomposing the carbonic acid sent up to the leaves by the roots—the oxyen being thrown off, and the carbon remaining to be conveyed back into the plant. This was called the *fixation of carbon.* It was now found, however, that the lymph is partially decomposed in its passage upwards, and that the oxygen set free is carried by the spiral vessels to the leaves, where it is exhaled. The superfluous water is also carried there and evaporated; and the greater part of the carbon contained in the descending sap is taken in by the leaves.

126. *The season of growth* is the period of the ascent and descent of the sap; and in those countries where plants have two seasons of growth, there are two periods of this change. This season varies in duration according to the nature of the tree. In the ash it is remarkably short; and though this tree retains its leaves only for a short period, opening them later and losing them sooner than many others, its wood is remarkably tough. The Scotch pine generally finishes its growth in the space of six weeks, and its young shoots are remarkably stiff and erect. The larch, on the contrary, which continues growing all summer, has long shoots, which are very flexible and slender.

127. *The ripening of the wood* of young shoots, is the complete formation of the first layer of wood; and in old trees it is the formation of a new layer of sap-wood, and the hardening of the sap-wood of the previous year.

128. *When the layer of new wood is completed,* mucilage and starch are deposited in its vessels, part of which oozes out in spring between the wood and the bark, which it loosens from each other; hence bark is easily removed in spring. This substance is called *cambium,* and is supposed to be the first form of the matter which afterwards becomes a new layer of sap-wood. The rest of the mucilage

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133. What of the respiration of plants?
134. Peculiarities of growth?
135. Define the technicals.

and starch deposited in the vessels of the alburnum is supposed to mix with the ascending sap, and to change its colour and taste in the manner before mentioned (par. 122).

129. *The sap-wood is always formed* from the descending sap; and thus, if a ring of bark be taken off a branch, the upper part of the wound heals rapidly, and the branch increases above it so much as to bulge out; while the lower part of the wound does not heal, and the branch beneath does not increase in thickness. Even tying a piece of cord tightly round a branch, so as to indent the bark and stop the current of the descending sap which passes through it, will make it swell above the ligature, and prevent its increase below.

130. *Every plant appears to have some matter conveyed to it by the lymph which it cannot assimilate.* When this matter is inorganic, it is deposited principally in the vascular tissue of the petioles and veins of the leaves, till they become choked up with it, and the leaves fall. The organic excrementary matter is, on the contrary, supposed to be exhaled from the leaves, or to be conveyed downwards by the descending sap (by means of the woody tube which passes through every root, even to the tip of the spongioles), and deposited in the soil. The season of growth being finished, the leaves fall off, leaving, however, in the axil of each a little bud, to be developed into leaves the following spring.

131. *The fall of the leaf* is supposed by De Candolle and many modern botanists to be occasioned by the deposition of inorganic matter in the veins and petioles, which in time so completely chokes them up, that the leaves being no longer able to receive nourishment from, or to transmit it to the tree, first lose their succulency and colour, and finally drop off. M. Du Petit Thouars, and others, however, suppose that as the petiole elongates, the spiral vessels it contains unrol, till at last they reach their full extent and break; then the leaf falls. Both opinions have been entertained by eminent botanists, but the former now appears to pre-

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136. What of superfluous nutriment?
137. Philosophy of the falling leaf?

vail; and it is confirmed by the fact, that dead leaves, when burned, yield more earthy matter than any other part of the tree.

132. *The motion of the sap has been attributed to various causes* by different botanists. Some suppose that it rises solely by the force of vital action; others that it is drawn up by the leaves; others that its particles are expanded and forced upwards by heat; and others that they rise by capillary attraction. The theory of Endosmose and Exosmose, broached by M. Dutrochet, is founded partly on this last opinion. This celebrated botanist discovered that small bladders of either animal or vegetable membrane, if filled with milk, and securely tied, when thrown into water, absorbed a quantity of that fluid and acquired weight; while on the contrary, if bladders were filled with water, and thrown into milk, they lost weight, from the water being attracted through the membrane into the milk. From these, and other experiments, he concluded, that if two fluids of unequal density be separated by a membrane, the heavier fluid will attract the lighter one through that membrane; and this he applied to the ascent of the sap, as he supposed that the greater density of the sap contained in the tree attracted the thin and liquid lymph taken up by the roots. He also found, that if an empty bladder immersed in water had the negative pole of a Galvanic battery introduced into it, while the positive pole was applied to the water outside, a passage of fluid would take place through the membrane; so that the rise of the sap might be effected in this manner by the agency of electricity. The passage of the water through the membrane he called *endosmose,* when the attraction was from the outside to the inside; and *exosmose,* when it was from the inside to the outside. Applying this theory to trees, it is said to be by endosmose that water is absorbed, either from the atmosphere or the earth, and that the ascending sap is drawn upwards. Another mode of accounting for the ascent of the sap was suggested by Du Petit Thouars, who is of opinion, that as soon as the warmth of spring has expanded the

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138. What of Dutrochet's theory?

particles of sap that are contained in the buds, their covering begins to swell; and as their size increases, fresh sap is attracted out of the adjoining parts, to supply the additional cellular tissue that is required. The parts thus emptied of their sap are refilled immediately by sap from those below; and thus the whole fluid is set in motion, from the extremity of the branches down to the roots. In corroboration of this last opinion, is the fact, well known to foresters and gardeners, that in spring the sap always begins to move first at the extremity of the branches. Dutrochet's theory, however, seems to be preferred by the greater number of botanists.

133. *An accumulation of the sap* takes place occasionally without appearing to cause any derangement in the ordinary functions of the organs; thus, nature not only lays up a store of elaborated juice to be ready to descend at the proper time every growing season, but also an accumulation, when necessary, for the production of flowers and fruit. It appears that the sap must be thickened by the various operations it undergoes in the leaves, before it be suitable for these purposes. It is also observed that the thickening of the sap, which is necessary for its accumulation, does not take place without the aid of heat and solar light; and thus, in cold wet situations, plants seldom produce so much fruit as in warm and dry ones. Abundance of carbon and nitrogen is further necessary; and scientific cultivators, having observed these facts, take advantage of them when they wish to throw trees into fruit, by keeping the roots so near the surface, as to be within the reach of atmospheric air, from which they obtain carbonic acid and nitrogen. They also bend the branches in training them against a wall, so as to prevent the too rapid descent of the sap, and to force it to accumulate in those places where they wish flower-buds to be produced. If a ring of bark be taken off a tree in spring, the sap will rise just the same as usual; but when the sap begins to descend, a protuberance will be formed just above the ring, which will be

139. Define the technicals.
140. What of the quantity and quality of sap?

occasioned by the accumulation of the sap; its further descent being stopped by the removal of the liber, which contain the vessels of the latex. This theory also explains why gardeners sometimes ring the branches of trees in order to throw them into fruit.

134. *The quantity of water thrown off by the leaves* of plants during the process of assimilation is very great. Before sunrise, even in the driest room, water may be seen hanging on the under side of the leaf, like drops of dew; or running down from the point, as though the leaf had been exposed to rain; but the heat of the sun soon dissipates this water, by converting it into vapour. Hailes found that the quantity of water exhaled by the leaves of a sunflower three feet and a half high, was from twenty to thirty ounces in twelve hours, or about seventeen times as much as is lost in the same time by perspiration in a healthy man. Plants exhale most moisture when exposed to the heat of the sun, as this powerful agent excites the vessels to more rapid action; hence newly transplanted plants are always put in the shade, lest their evaporation should be greater than their weakened roots can supply; and hence, also, when plants want water, their leaves flag. The leaves of succulent plants have scarcely any stomata; hence they bear the want of water for a considerable time without injury. In some leaves, such as those which are pinnatifid or pectinate, there is very little cellular tissue; but the principal ribs of the venation are always perfect, and it is through these that the circulation and elaboration of the sap is carried on. It was formerly supposed that in darkness plants gave out nearly as much carbonic acid gas as they had absorbed, and absorbed nearly as much oxygen as they had given out during the day; but the experiments of Professor Daubeny, at Oxford, have proved that this is only the case when plants are in an unhealthy state. There can be no doubt that all the vital actions of a plant are stimulated by heat and solar light; and it is well known that colour is chiefly dependent on light, as plants grown in darkness are nearly white. If air be partially or entirely

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141. What of the exhalation of water from plants?

excluded, the plants become *etiolated*, or blanched; their stems and leaves want firmness, their flowers are imperfectly developed, and their fruits do not ripen.

135. *The progress of a tree from germination to maturity* is comparatively rapid, particularly during the first years of its existence, as it every year increases in size by the deposition of fresh layers of wood and the formation of additional branches. It also increases in height by new matter forming at the extremity of its ascending shoot, though not by the distension of any part already formed. This has been proved by inserting pegs in the trunk of a tree, which, in the course of two or three years, were found to be still at the same distance from each other as at first, though the tree itself had increased considerably in height during that period.

136. *The progress of a tree from maturity to decay* is slow. For some years after it has reached its full growth, very little change is perceptible; but at last the heart-wood begins to decay in the centre, and gradually wastes away, till only a hollow trunk encased by little more than the alburnum and the bark is left. The vigour of the tree is now sensibly diminished; but as the circulation of the sap is carried on in the alburnum and bark, buds are still formed; though the growing point seldom elongates itself into a branch. The flowers and fruit next cease to be produced, and finally, even the leaves disappear. Life is now extinct; but the tree still stands, till it becomes rotten at the base from the moisture of the soil, and then the first storm that comes blows it down. By and by it crumbles into vegetable mould; but this decomposition is strictly a chemical process: it takes place in vegetable just as in mineral substances, and has no connection whatever with organic functions.

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142. What of the progress of trees to maturity?
143. Describe the process of decay.

ORGANS OF REPRODUCTION—FLOWER-BUDS, FLOWERS, FRUIT, AND SEED.

137. The organs of reproduction are the flowers, the fruit, and the seed; and these, or some modification of them, must exist in every perfect *Phanerogamous* or flowering plant.

138. Flower-buds are produced like leaf-buds, from which they differ chiefly in containing one or more incipient flowers within the leaves; the flowers being wrapped up in their own floral leaves, or bracts, within the ordinary leaves, which have their usual outer covering of scales. The growing point is generally developed when the leaves expand, but it is short and stunted, and unlike the branches produced from the leaf-buds. Every flower-bud, as soon

Fig. 54.—Bractea of the Christmas Rose and the Lime-Tree.

as formed in the axil of the old leaf, contains within itself all the rudiments of the future flowers. If a bud be gathered from a lilac or a horse-chestnut very early in spring, all the rudiments of the future leaves and flowers will be found within it, though the bud itself may not be more than half an inch long, and the flowers not bigger than the points of the smallest pins.

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144. What of the organs of reproduction?
145. What of rudimental flowers?

139. *Bracts* are leaf-like bodies, which appear to bear the same relation to flowers that stipules do to leaves. In some

Fig. 55.—The Spathes of the Arum and the Narcissus.

cases the bract appears to form a sheath for the flower, as in the lime (see *b* in fig. 54): in others it resembles a *calyx*, as in the Christmas rose (*a*). In some plants the bract takes a tube-like shape, when it is called a *spathe*, as in the Arum (*a*) and the Narcissus (*b*, see fig. 55); in others it supplies the place of a floral envelope, as in the *glume* of the oat (fig. 56). When two or more bracts are joined together, they form an *involucre* (see *a b* in fig. 57); and when very numerous, they form a *cupule*, or cup, as in the husk of the chestnut and the beech, the cup of the acorn, &c. Bracts, when very

Fig. 56.—Glume of the Oat.

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146. Describe the bracts.
147. What are varieties of bracts?

small and membranous, are called *palea,* as those of the florets of the dahlia; and when imbricated, *scales,* as in the globular involucre of the cotton thistle. The small leaves found growing on a flower-stalk below the smaller tufts of flowers are called *bractioles* or *bractlets* (*c* in fig. 57).

Fig. 57.—Involucres of the Phlox (*a*), and Chinese Primrose (*b*); and Bractioles of the Phlox (*c*).

140. *The stalk* of a single flower is called the *peduncle;* but if several flowers be clustered together, the axis, or central stalk, is called a *rachis*, and the stalks of the separate flowers *pedicels.* When a flower has no peduncle, but is directly attached by its base, it is said to be *sessile.*

141. *The æstivation* of flowers signifies the manner in which they are folded in the bud, and this differs in different plants; as, for example, the petals are *crumpled* in the poppy, *plaited* in the *petunia, convolute* in the pink, and *twisted* in the *convolvulus.*

142. *The position of flowers on the branch* is either *terminal* or *axillary,* and they are produced either singly or in clusters.

143. *The form of inflorescence,* or manner in which flowers are arranged when several are produced together,

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148. Define the technicals of this page.
149. What of the diversity in flowers?

vary exceedingly; but the following are the most common:—*A raceme* is when numerous flowers are produced on an elongated simple rachis, each flower having a separate pedicel, as in the laburnum; a *thyrse* is a raceme with branched pedicels, as in the lilac; a *panicle* is a loose thyrse, with flowers on long pedicels, as in the oat; a *spike* has its flowers sessile—that is, without pedicels, on an elongated simple rachis, as in the veronica, or speed-well; a *spadix* is a spike with a thick fleshy rachis, on which the flowers grow all round, and as closely together as possible,

Fig. 58.—Raceme, Spike, Umbel, and Cyme.

as in the arum; an *amentum*, or catkin, is a spike, the flowers of which have bracts instead of floral envelopes, and the rachis of which is articulated, so as to fall when it withers, as in the walnut and the poplar; a *head* of flowers has a great many sessile florets attached to a flat or globular fleshy axis, called a receptacle, which is surrounded by an involucre, as in the daisy; an *umbel* is a head with the florets on pedicels, and the axis not fleshy, as in the parsley; a *compound umbel* has several small umbels on branched pedicels springing from a common axis; a *corymb* has some of the pedicels of the flowers longer than others, so that the flowers form a flat head, as in the yarrow; a *cyme* has the pedicels of the same length, so as to form a round

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150. Explain the technicals.

head, as in the elder; and a *fascicle,* or bundle, as in the Sweet William, is a kind of compound cyme.

144. *The modes of expansion* are the different ways in which clusters of flowers open. When a spike is coiled, and unrols as the flowers open—as in the Forget-me-not—the mode of expansion is said to be *gyrate.* When clusters of flowers begin to open first at the base, or in the outer circle, their mode of expansion is said to be *centripetal;* but when the uppermost flowers, or those in the inner circle, open first, their expansion is called *centrifugal.* Sometimes the mode of expansion is irregular, but this is generally when some of the florets are abortive.

145. A FLOWER consists of a pistil, and one or more stamens, having generally one or more coverings called floral envelopes, to protect the stamens and pistil, which are destined for the production of the seed. To understand the appearance of these parts, we need only take a rose, the green covering of the bud of which is called the *calyx,* and the pink part the *corolla.* These are the two floral

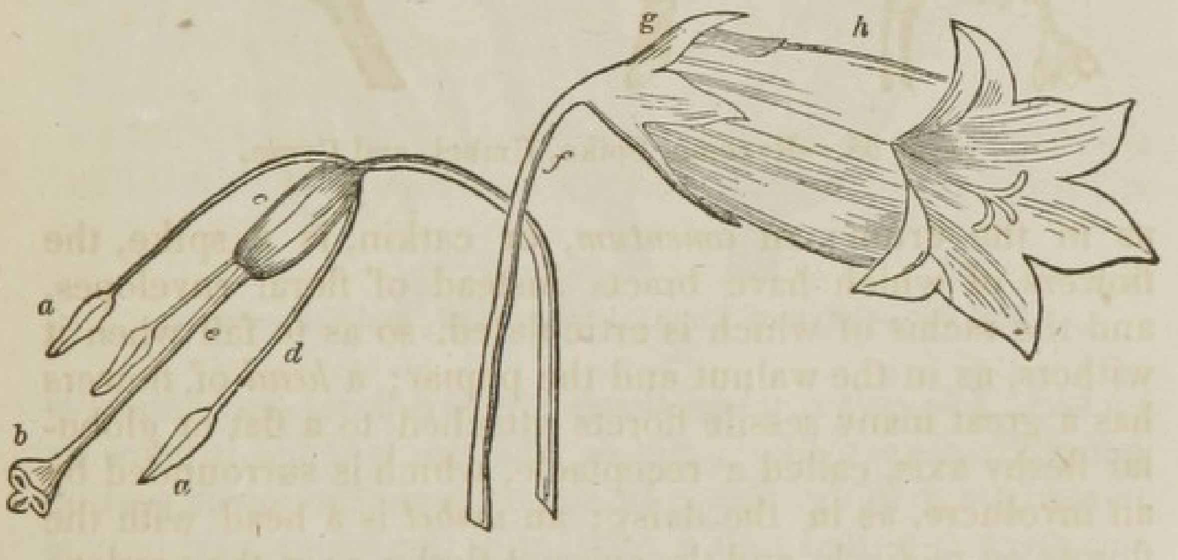

Fig. 59.—*a a,* Stamens; *b,* Stigma, or Summit; *c,* Ovary, or Seed-Bag; *d,* Filament; *e,* the Style; *f,* Peduncle; *g,* Calyx; *h,* Corolla.

envelopes. When the rose opens, it displays in the centre of its coralla a bunch of yellow thread-like substances, which are the *stamens,* and in the middle of them, though

151. Differences in mode of expansion.
152. Analyze a flower, and define.

scarcely to be perceived, is the *pistil.* Other flowers have the same parts, as shown in fig. 59.

146. *When there are two floral envelopes,* the outer one is called the *calyx,* and the inner one the *corolla;* but when there is only one, it is called the calyx. When the calyx and corolla are so mixed as to be scarcely distinguishable from each other, as in the tulip, the floral envelope is called the *perianth;* and this term is sometimes applied to the calyx and corolla, when not confounded together. When there is no floral envelope, flowers are said to be *apetalous.*

147. *The divisions of the calyx* are called *sepals,* and those of the corolla *petals;* when the calyx and corolla are confounded together, the divisions of the floral envelope are called the *segments* of the perianth. When the divisions of the corolla adhere at the margins, so as to appear united, the flower is said to be *monopetalous.*

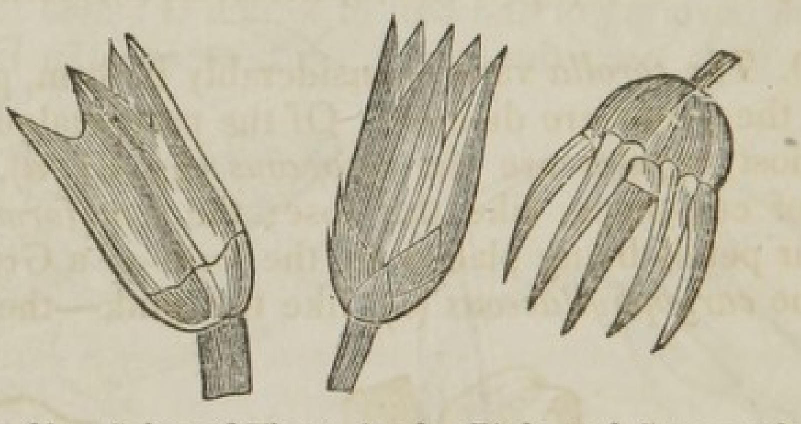

Fig. 60.—Calyx of Thorn Apple, Pink, and Campanula.

148. *The calyx,* when there are two floral envelopes, is generally shaped like a cup or chalice, whence it takes its name (see *g* in fig. 59). In some plants the lower part of the calyx is united into a tube, and the upper part only is divided; when this is the case, the upper part is called the *limb.* The limb of the calyx is generally said to be divided into *lobes,* or segments; but in some of the Compositæ, it is cut into a kind of fringe called *pappus,* as exhibited in the thistle, it being the part which crowns the seeds, or

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153. Varieties in flowers.
154. Define all the technicals.

rather pericarps, of that plant, and by means of which they are dispersed by the winds.

149. *When there is only one floral envelope*, the calyx generally takes an irregular form; and this is also the case where the petals are less conspicuous than the sepals. In the larkspur, for example, the calyx takes a *calcarate*, or spur shape; and in the monkshood, a *galeate*, or helmet shape.

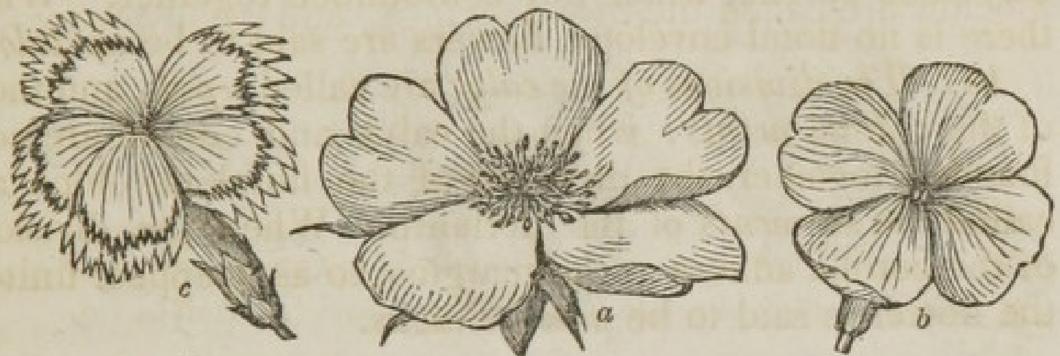

Fig. 61.—Caryophyllaceous (*c*), Rosaceous (*a*), Cruciform (*b*).

150. *The corolla* varies considerably in form, particularly when the petals are distinct. Of the polypetalous corollas, the most regular are the *rosaceous* (fig. 61, *a*), forming a kind of cup-shape, like the rose; the *cruciform* (*b*), from its four petals being placed in the form of a Greek cross; and the *caryophyllaceous* (*c*), like the pink—the latter be-

Fig. 62.—Nectiferous Spurred (*b*), Lilaceous (*a*), Papilionaceous (*c*).

ing remarkable for its petals, which have a very long *unguis*, or claw, enclosed in the calyx, and a broad spreading limb

155. Names of diversified forms.

above it. The other most interesting forms of this kind of corolla, are the *lilaceous* (fig. 62, *a*), like the common lily; the *nectiferous spurred* (*b*); and the *papilionaceous* (*c*), so called from its resemblance to a butterfly. The latter corolla consists of five petals, the largest of which stands erect, and is called the *vexillum*, or standard; two smaller ones below are called the *alæ*, or wings; and the lower two,

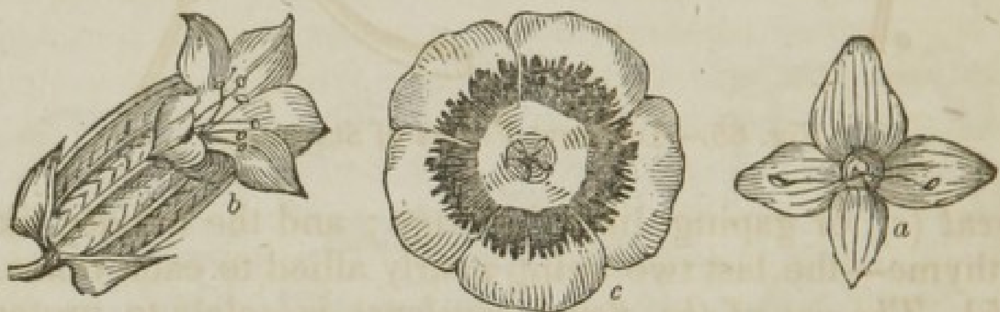

Fig. 63.—Campanulate (*b*), Hypocratiform (*c*), Rotate (*a*).

which are united in the form of a boat, are called the *carina*, or keel. There are many other curious forms of corollas, such as those of the *calceolarias*, the *orchidaceæ*, the *aristolochias*, &c. Of the *monopetalous* corolla, there are seldom more than six regular forms; namely, *rotate* (fig. 63, *a*), or wheel-shaped, like the mezereum; *campanulate* (*b*), or bell-shaped, like the campanula; *hypocratiform* (*c*), or

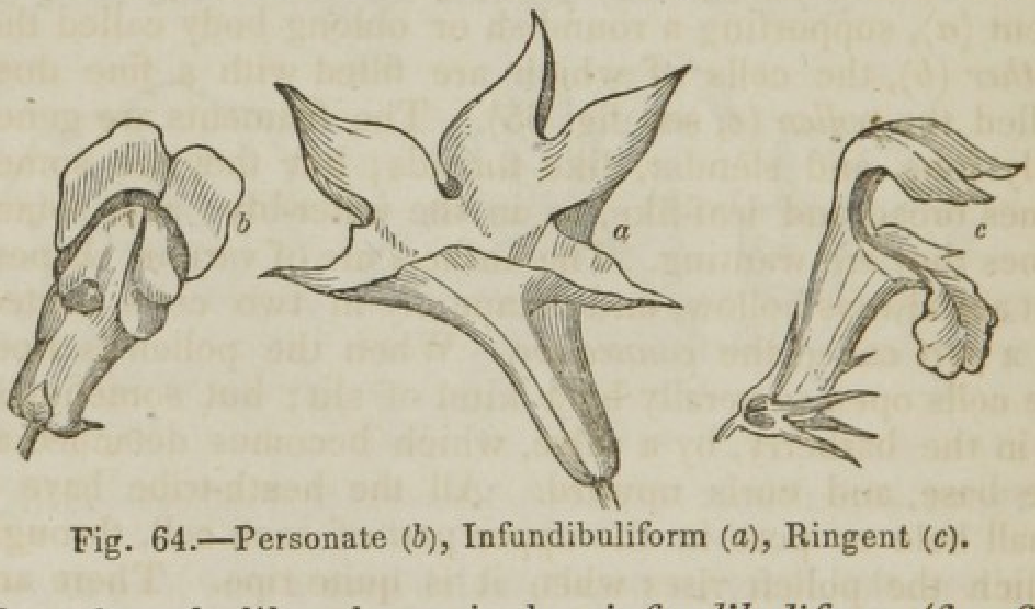

Fig. 64.—Personate (*b*), Infundibuliform (*a*), Ringent (*c*).

salver-shaped, like the auricula; *infundibuliform* (fig. 64, *a*), or funnel-shaped, like the convolvulus; *urceolate*, or pitcher-shaped, like the arbutus; and *tubular*, like the blue gentian. Of the irregular forms, the principal are the *personate* (*b* in fig. 64), or masked, like the snap dragon; the

Fig. 65.—Different Forms of Stamens.

ringent (*c*), or gaping, like the sage; and the *labiate*, like the thyme—the last two being nearly allied to each other.

151. *The use of the floral envelopes* is solely to protect the stamens and pistil from injury; and thus, though we are in the habit of considering the corolla to be the flower, it may be wanting without injury to the plant; so that a flower may be without petals, or any other floral envelope, the important parts being the stamens and pistil. In the same manner, every seed-vessel is, in the language of botanists, considered a fruit, the botanical use of the fruit being only to serve as a covering for the seed.

152. *The stamens*, when perfect, consist of a stalk or filament (*a*), supporting a roundish or oblong body called the *anther* (*b*), the cells of which are filled with a fine dust called the *pollen* (*c*, see fig. 65). The filaments are generally long and slender, like threads; but they are sometimes broad and leaf-like, as in the water-lily; and sometimes they are wanting. The anthers are of various shapes, but are always hollow, and commonly in two cells, united by a part called the *connective.* When the pollen is ripe, the cells open generally by a kind of slit; but sometimes, as in the barberry, by a valve, which becomes detached at the base, and curls upward. All the heath-tribe have a small hole or pore in the upper part of each cell, through which the pollen rises when it is quite ripe. There are

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156. What is the function of the envelope?
157. What of the stamens, anther, and pollen?

three kinds of anthers, namely, *adnate* (*d*), in which the filament is attached to the back of the connective, from one end to the other; *innate* (*e*), in which the filament is inserted in the lower part of the connective; and *versatile* (*f*), when the filament is inserted in the middle of the connective, but so slightly, that the anther moves with every breeze. The connective is sometimes drawn out into one or two spur-like bodies called *appendages*, as in the whortleberry and the violet. The pollen, though to the naked eye apparently only a fine dust, will be found, when examined by a powerful microscope, to consist of a number of curiously formed grains, each of which is filled with fluid. The shape of all the pollen grains of one genus is the same; as, for example, in all the species of the evening primrose, they are triangular; those of the spider wort are cylindrical and curved, and those of the bladder senna are square. Each grain has two distinct coverings, and the fluid which it contains is crowded with a multitude of minute particles all in active motion, and generally quite distinct from each other, though the largest is not more than the five-thousandth part of an inch in length. In most cases the grains of pollen are also quite distinct; but in the evening primrose they are connected by slender threads, and in some other genera they adhere in clusters. In the orchidaceæ and the asclepedaceæ the grains of the pollen form solid and wax-like masses. When the pollen falls upon the

Fig. 66.—Pistils.

158. What varieties of anthers?
159. How is the pollen shaped?
160. Describe the varieties.

stigma, each grain sends down a long slender tube, through which the fluid it contains, and all its minute particles, are carried downwards to the ovary.

153. *The pistil* consists of a hollow part called the *ovary*, or seed-vessel (*a* in fig. 66), which is generally surmounted by a hollow tube called the *style* (*b*), supporting a porous substance termed the *stigma* (*c*), which is not covered by any epidermis. The stigma is of various shapes, and sometimes it is even leafy, as shown in fig. 66 at *d*. It is most commonly, however, divided into several lobes, sometimes called *stigmata*, as shown at *c*. Fig. 67 shows some

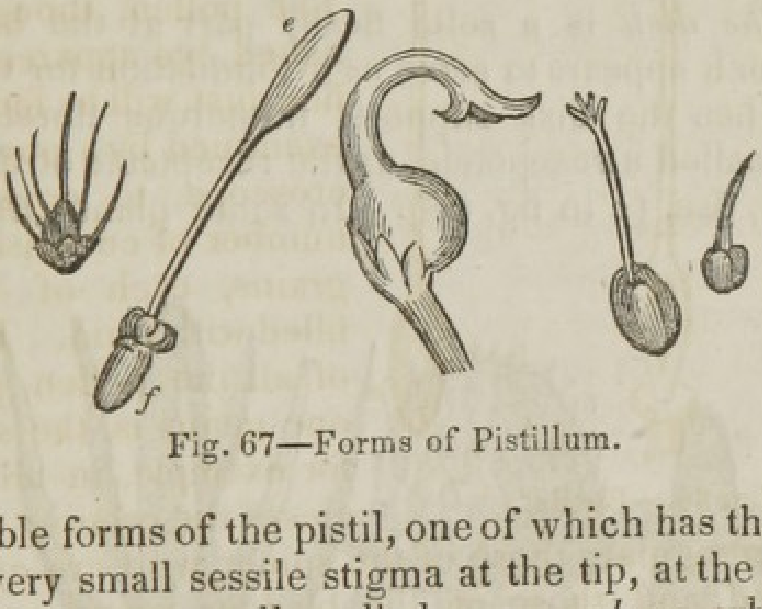

Fig. 67—Forms of Pistillum.

remarkable forms of the pistil, one of which has the ovary (*e*) with a very small sessile stigma at the tip, at the extremity of a long stipes or stalk, called a *gynophore*, which looks like a style, the part which looks like an ovary below, at *f*, being the receptacle which bears the stamens. The caper has this kind of pistil. The ovary, when young, will generally be found, if cut open, to be divided into cells by partitions, which are called *dissepiments*, or *septa;* but these partitions frequently disappear altogether, or at least become imperfect in the ripe fruit. In all ovaries there is a kind of string or nerve called the *placenta*, to which the incipient seeds, or ovules, are attached; and which, when it adheres to the sides or walls of the ovary, is called *parietal;* but when it forms a column in the centre, is said to

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161. Of what parts does the pistil consist?
162. Define all the technicals italicised.

be *free central.* The ovary is generally sessile, but it is sometimes placed on a short thick stalk, called a *stipe.* When there are several ovaries in one pistil, they are called *carpels.* Enclosed in the ovary are the rudiments of the future seed, which are called *ovules.* When these are first formed they are quite soft; but if closely examined, they will be found to consist of two or more skins with a little pulp inside, each having a very small opening which is imperceptible to the naked eye, called the *foramen.* When the tube of the pollen descends into the ovary, it enters this little opening, and thus the fertilizing fluid is conveyed into the ovule.

154. *The disk* is a solid fleshy part at the base of a flower, which appears to serve as a foundation for the other parts. When the disk supports numerous florets or carpels, it is called a receptacle, as the receptacle of the daisy, the teazel, &c. (*c* in fig. 68). In some plants, the recep-

Fig. 68.—Receptacles of Raspberry (*a*); Strawberry (*b*); Teazel (*c*).

tacle becomes detached from the carpels when they ripen, as in the raspberry (*a*), and in others it becomes distended and juicy with the ripe carpels still upon it, as in the strawberry (*b*). In other cases, the receptacle lines the calyx which surrounds the ovary, and becomes the fleshy part of the fruit, as in the apple and pear, the peach, &c.; and sometimes the receptacle, turned inside out, encloses the flowers and seeds, as in the fig.

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163. What of the disk, and its variety of function?

155. *Appendages of a flower* are those parts the use and nature of which have not been exactly defined, and which Linnæus called by the general name of *nectaries*, from the fact that most of them secrete the saccharine fluid or honey found in many flowers. Of these appendages or supernumerary parts are the rays of the passion-flower, the trumpet-shaped cup of the narcissus (*b* in fig. 62), the scale at the base of the petals of the butter-cup, the indusium of the Lechenaultia, &c. These appear, however, to be abortive organs; as, for example, the rays of the passion-flower are imperfect stamens, and the corona of the narcissus consists of the filaments of imperfect stamens grown together. This tendency of the parts of a plant to change their form by growing together, is frequently exemplified in the leaves and bracts.

156. A FRUIT, in botanical language, is simply a seed-vessel, which is sometimes enveloped in a hard and dry, and sometimes in a fleshy covering, or *pericarp*.

157. *All seed vessels are either dehiscent or indehiscent.* They are called dehiscent when they open naturally to discharge their ripe seeds, and indehiscent when they do not do so. The place of opening is generally marked by lines or *sutures*, and the parts into which they separate are called *valves*. The dehiscence of a seed-vessel is said to be *septicidal* when it opens at the dissepiments, and *loculicidal* when it opens between the dessepiments; but these last two terms are not in general use.

158. *The most common kinds of seed-vessels* are the following:—The *follicle* (see fig. 69), a dehiscent many-seeded carpel, with one valve and one suture, generally growing two or three together; and the *legume* (*a* in fig. 70), a

Fig. 69.—Follicles.

164. Name the appendages, and their character.
165. Define fruit and pericarp.
166. What seed-vessels are dehiscent and indehiscent?
167. Name the varieties most common.

dehiscent many-seeded carpel, with two valves and two sutures, the placenta bearing the seeds being attached to the *dorsal* or back suture. The *capsule,* which is dehis-

Fig. 70.—A Legume and a Pome.

cent, dry, and many-seeded, is composed of several carpels joined together, which either form one large cell, as in the poppy, or are divided into several cells, by the dissepiments. The *silique,* which is long and narrow, and the *sillicle,* which is short and broad, are formed of two carpels, joined together with a central membranous placenta; they are dehiscent, and open into two valves. The *nut* is dry, bony, one-celled, and indehiscent. Nuts are of various kinds, from the hazel-nut (*c* in fig. 71) to the hard bony seed of

Fig. 71.—Raspberry and Nut.

the rose and cratægus. The seed of the acer, which is a nut, is enclosed in a thin membrane, and called a *samara,* and the acorn is a nut of a peculiar kind, called a *gland.* The loose covering of the filbert, and the cup of the acorn,

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168. Define the technicals.

are both different states of the *involucre*. The *achenium* is a dry, bony, indehiscent, one-celled carpel, the pericarp of which drops with the seed, but does not adhere to it; the *caryopsis*, on the contrary, is an indehiscent one-seeded membranous carpel, the covering of which not only drops with the seed, but adheres to it firmly, as in wheat, the covering of which is only separated after grinding in the form of bran. Of the other kinds of seed-vessels, the *pyxis* or *pyxidium*, is a capsule which opens transversely, as in the anagallis; the *etærio* (a term not in common use) is a collection of one-seeded berries adhering together, as in the raspberry (*d*); and the *berry*, when ripe, has numerous loose seeds buried in pulp, the seeds when unripe adhering to *parietal placentas*, as in the gooseberry. The *pome* (*b* in fig. 70) is what is called a kerneled fruit; that is, it consists of two or more cartilaginous or bony carpels, joined together, and enclosing the kernels or seeds; the whole being surrounded by the fleshy lining of the tubular part of the calyx, the leafy limb of which remains on when the fruit is ripe, and is called the *eye*, as in the apple and pear. The *drupe* (see fig. 72) is a stone fruit; that is to say, its seed or kernel is enclosed in a bony nut, called the *endocarp;* over this is the fleshy lining of the calyx, which becomes a juicy pulp, and is called the *sarcocarp;* and this is covered with a thick downy skin, or *epicarp*. It will be observed, that all the fruits hitherto mentioned have each sprung from one flower, part of one of the floral envelopes of which (the calyx) has become the pericarp of the seeds; in the fig, however, a great number of flowers are found in one fruit, which consists of the dilated receptacle of the florets; and in the pine apple and bread fruit, the eatable part consists of the thickened bracts

Fig. 72.—Drupe (Section of a Peach).

169. Explain the technicals in italics.

of a number of flowers, which have grown together, and become pulpy.

159. THE SEED contains the *embryo* or germ of the future plant, which is generally surrounded by a nutritious substance termed the *albumen*. The whole seed is covered with a thick skin or outer integument called the *testa*, one end of which has a strongly-marked round scar or *hilum*, which shows where the seed was attached to the placenta. Sometimes the seed is sessile; but at others it has a little *funicle* or footstalk growing out of the hilum, or a thick fleshy skin called an *axil*, by which it hangs to the placenta. Within this testa is a second or inner integument, which is scarcely discernible from the first, and within this is the *nucleus* of the seed, containing the embryo. Near the radicle point of the embryo, and generally at the end opposite to the hilum, is a small opening through both the integuments to the nucleus, called the *microphyle* or *foramen*. Sometimes there is also on the testa, as in the orange, a mark where the skins of the outer and inner integuments join, which is called the *chalaza;* and a kind of nerve, called a *raphe*, which runs from it to the hilum.

160. *The chalaza* marks the point of union between the two membranes of the testa and the nucleus, and it is always exactly opposite the foramen. Sometimes it is close to the hilum, but at others it is distant from it, and the two are only connected by the vessels of the raphe. These organs, which consist entirely of spiral vessels and ducts, without any woody fibre, are sometimes collected into a projecting cord, and sometimes beautifully spread over the testa, as in the seeds of the orange and lemon. In those seeds where the hilum is exactly opposite the foramen, there is no chalaza, and of course no raphe, as the one cannot exist without the other.

161. *The axil* is a fleshy substance, which envelopes the seed, covering the testa. It is only found in some plants;

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170. What are the contents of the seed?
171. The analogy between animals and plants in their organs and process of reproduction, and names.
172. Define the italicised words.

as, for example, in the nutmeg, of which it forms the mace; and in the seed of the enonymus, or spindle-tree, in which it is unusually large. It serves as a kind of funicle, and is, in fact, an enlargement of the placenta.

162. *The nucleus* of the ovule consists of a soft pulpy matter, which in the ripe seed becomes changed into the embryo and the albumen; or the embryo only, if there should be no albumen.

163. *The albumen* is the store of nourishment which nature has laid up for the support of the young plant, before its organs are sufficiently matured to allow of its supporting itself. In most cases this matter surrounds the embryo; but sometimes it forms part of the cotyledons, and at others it is wanting altogether. Even where it exists, it varies very much in quantity, sometimes being much smaller than the embryo; while in other cases, as, for example, in the cocoa-nut, the albumen weighs as many, or more ounces, than the embryo does grains. The albumen varies in quality as much as it does in quantity. It is generally fleshy, as in the pea and bean; but sometimes it is farinaceous or floury, as in the wheat and in the marvel of Peru; at other times it is oily, as in linseed; horny, as in the coffee; or even stony, as in the kind of palm whose seed forms the substance called vegetable ivory. In the nutmeg and the custard apple tribes, it appears to be perforated in every direction by a mass of dry cellular tissue; and an embryo of this kind is said to be *ruminated.*

164. *The outer integument* of the seed consists of two parts, the outer one of which is called the *primine,* and is merely a cellular coating traversed with veins; the inner one, which is called the *secundine,* sometimes adheres so closely to the outer one, that it is difficult to separate them, unless the ovule be examined at a very early period of its growth. The outer of these coverings being intended to protect the seed from injury, is frequently of a hard, bony, or leathery texture, and its surface is generally smooth and polished. Sometimes, however, the surface of the seed is

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173. Varieties of albumen.
174. Describe the integuments or membranes.

rough, and it is either winged, or covered with tufts of hair, called *coma*, which are intended by nature to aid in the dispersion of the plant. The seed of plants belonging to the asclepiadaceæ is covered with a fine silky down, and that of the cotton plant with cotton. The seeds of the Black Italian poplars are also buried in a cottony substance. Occasionally the outer integument is furnished with veins, so as to form a kind of network; and in other cases it forms a membranous covering, as in the seed of the orange. The inner membrane is generally white, and so thin, that it looks like a lining to the other. When the ovule first forms, a portion of the inner membrane frequently projects at the foramen, having the appearance of a little cup-shaped stigma, but this part disappears as soon as the pollen tube has entered the foramen. Occasionally there are three coverings to the ovule; but when this is the case, the inner one adheres closely to the pulpy part of the seed. Sometimes there is a protuberance on the testa, called a *caruncle.*

165. *The embryo of an exogenous plant* is said to consist of three parts; the radicle or root, the cotyledons or seed-lobes, and the plumule or ascending shoot; but to these may be added a fourth, the collar or neck. Of these, every embryo must have a radicle and a plumule, with the connecting point or collar between them; but the cotyledons are not so essential; and in some cases—as, for example, in the cyclamen and the dodder—they are wanting altogether. It is generally supposed that every exogenous plant has two cotyledons, and hence these plants are called *dicotyledonous;* but the sycamore has three cotyledons; the forget-me-not, and other plants of the same tribe, four; and the pine and fir-tribe from two to twelve; while in the horse-chestnut and the oak, the cotyledons grow together, so as to appear but one. In other plants—as, for example, in the marvel of Peru—the cotyledons are unequal in size, one being nearly twice as large as the other. The cotyledons of this plant, and those of the sycamore, are strongly veined, like leaves, in the seed; and the latter, which are very long, are curiously wrapped up in the bud.

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175. What of the parts of the embryo?

166. *The position of the embryo* in the seed varies in different plants; but the root always points towards the foramen, as the root is the first part that makes its appearance, and it is always through this opening that the young plant emerges from the seed. The little hole that marks the foramen is so very small in the ripe side, that it would escape the attention of any but a botanist; but when there is no chalaza, it is always opposite the hilum, which is generally very conspicuous; and when there is a chalaza, its position is marked by the projecting cord or raphe. The embryo is said to be straight when its radicle points towards the hilum, as in the appl: and the pear, the cotyledons of which fill the whole seed, and are enclosed in the broadest end. In other cases the cotyledons point towards the hilum, and when this is the case, there is no raphe, as the chalaza is always close to the hilum. In the primrose tribe, the embryo lies across the seed; and in the convolvulus, it is coiled up in a spiral manner. It is also often

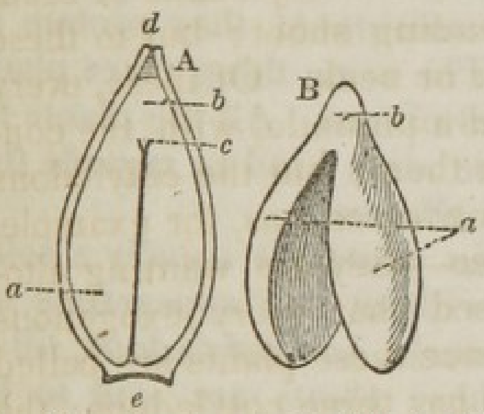

Fig. 73.—Seed entirely filled with the Embryo.

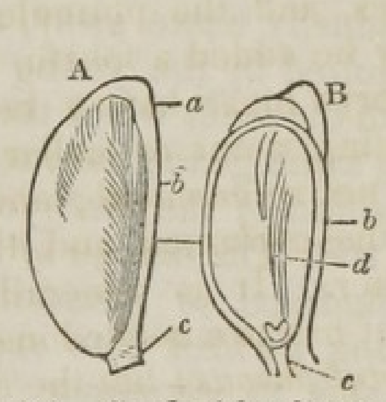

Fig. 74.—Seed with a large Albumen and small Embryo.

curved when the hilum is half way between the foramen and the chalaza. The embryo is always in the same position in every plant of the same genus, and even of the same order. In fig. 73, A shows a seed of the candleberry myrtle, which is entirely filled with the embryo, cut in two. In this *a* is one of the cotyledons, *b* the radicle, and *c* the place between the cotyledons from which the plumule

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176. Varied positions of the embryo.

springs, *d* is the foramen, and *e* the hilum. B shows the embyro picked out of the seed with the cotyledons (*a*) partly divided, and the radicle (*b*) before it begins to elongate. Fig. 74 at A shows the outside of a seed of the red currant, with the chalaza at *a*, the raphe at *b*, and the hilum at *c*. B is the same seed split in two, showing the section of the raphe (*b*), the large albumen (*d*), with the little embryo at the base, with its root pointing towards the hilum (*c*), the foramen being just above it.

167. *In every ripe seed* a quantity of nearly pure carbon and a small quantity of gluten are laid up for the nourishment of the future plant, either in the albumen or in the cotyledons. The latter, when not fleshy, always rise above the surface of the ground in the shape of leaves (called seed or *seminal* leaves), though their form is different from that of the true leaves. Sometimes fleshy cotyledons do the same, as in the lupine; but generally they remain in the ground, as in the horse-chestnut, the oak, and the broad bean. The cotyledons, when leafy, fall off when the true leaves expand; and when they remain in the ground, they gradually waste away, as the nourishment they contain is required by the young plant. The same thing takes place with the seeds when they are albuminous. All the plants in the same genus have seeds of the same kind as regards the position of the embryo and the albumen.

168. *The embryo of endogenous plants* is usually a solid cylindrical or roundish body, without any appearance of being divided into radicle, plumule, and cotyledons, till it begins to germinate; hence these plants are said to be *monocotyledonous*. In germinating, the single cotyledon always remains in the ground, enclosed in the testa of the seed, while the root protrudes and elongates considerably before any plumule appears. In some of the endogens, the embryo has a second or accessory cotyledon; but this is always very small and imperfect.

169. *From the structure of the embryo* the terms *dicotyledonous* and *monocotyledonous* are generally used indiscrimi-

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177. Composition of ripe seed.
178. Describe the varieties in the structure of the embryo.

nately for exogenous and endogenous; while *cryptogamous*, or flowerless plants, from being propagated by sporules instead of seed, are said to be *acotyledonous;* that is, without any cotyledon whatever.

FUNCTIONS OF THE ORGANS OF REPRODUCTION.

170. THE FUNCTIONS OF THE ORGANS OF REPRODUCTION are strongly marked; for, as the production of the future plant entirely depends on the formation of the seed, more than usual means have been provided for enabling plants to lay up a stock of nutritious sap for the formation of the different parts of the flower. The proper juice, which has been matured in the leaves, passes through the peduncle to the calyx, which is generally furnished with hairs, to collect moisture from the atmosphere, and thus enable the plant to procure a sufficient quantity of nitrogen, as the starchy matter contained in the proper juice requires to be converted into sugar before it can afford nourishment to the organs of reproduction, and this sugar it deposits in the disk of the flower. This process is repeated by fresh sap constantly rising, and none returning, till at last the disk of the flower becomes so charged with sugar, that it escapes in the form of honey. In some cases this liquid honey is so abundant, as to half-fill the cup of the flower, as in the Nepaul tree rhododendron. The sugar thus deposited serves to nourish the stamens and pistils, the anthers enlarge, and their cases become filled with pollen; while, on the other hand, the ovary forms, containing within it the ovules or incipient seeds. At length the anthers burst, and the pollen falls on the stigma, which exudes a slightly glutinous fluid, to which the grains of pollen adhere, and each then sends down a delicate membrane in the shape of a tube, which passes between the cells of the style, and entering the ovary, penetrates each ovule through the foramen.

171. *The curious formation of the grains of pollen* has

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179. What of the functions of these organs?
180. Describe the process of reproduction in plants.
181. Office and peculiarities of the pollen.

been already alluded to; and it will be seen, on a close examination, that the outer coat of the grain bursts when it is ripe, and that the inner coat elongates itself into the shape of a tube. The cells of the stigma are also beautifully contrived to admit the passage of these tubes, as they are long and extremely loose in texture; at the same time so moist and elastic as to be easily compressed when necessary. It is so contrived, that the minute particles contained in the grains enter slowly to the ovary, as it seems necessary that the fecundating matter should be admitted by degrees. It is also necessary that the tube should enter the foramen of the ovule, and as the ovule is not always in a proper position to receive it, it will be found to erect itself, or to turn, as the case may be, while the granules of the pollen grains are passing down the tubes. The tubes of the pollen grains do not appear till the pollen touches the stigma, and they then gradually elongate, forming fresh cellular tissue at the extremities, till they become sufficiently long to reach their destination. The formation of the new cells at the extremity of the tubes may be seen by a powerful microscope. The ovules are also fed at the same time by starchy matter absorbed from the ovary through the placenta, to which they are attached.

172. *When the seed has been fecundated by the pollen*, the petals and stamens of the flower fade, but the calyx sometimes remains attached to the ovary, in which the seeds now rapidly develope themselves, being fed with the rich sap which continues to rise through the peduncle. In most forest trees, the *pericarpium*, or covering of the seed-vessel, is dry; but in fruit trees it is fleshy. When this is the case, it is generally a part of the disk which becomes eatable. In all the British stone and kernel fruits, the eatable part is a portion of the disk which lines the tube of the calyx, and which thus forms a covering to the ovary. The epidermis of the calyx has scarcely any pores, and consequently, as the oxygen contained in the sap cannot escape, when the latter is decomposed, to deposit the carbon in the seed, this

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182. How is the embryo nourished?
183. Describe the process of ripening.

part becomes intensely acid. When the seed is ripe, it ceases to require any more carbon, and this substance is deposited in the pulp, which now loses its acidity, and becomes sweet. In some fruit—as, for example, the peach—the epidermis is furnished with hairs to collect moisture from the atmosphere, and consequently this fruit abounds in juice.

173. *Some plants ripen their fruit* in a much shorter period than others; and this process is greatly facilitated by increase of temperature. In many, the seed is ripe in a few days after flowering; in the grape it takes from fifteen days to a month; in the rasp and strawberry about two months; in the horse-chestnut four; in the apple and pear five; in the beech and walnut six; in most pines about a year; and in some oaks eighteen months. The peduncle, when no longer wanted to convey nourishment, withers, and the fruit falling to the ground, begins gradually to decay; and in this process the mass of pulpy matter, abounding in carbon, attracts oxygen from the atmosphere, and thus forms a supply of carbonic acid gas admirably adapted for the nourishment of the young plant, which the return of spring raises from the seed. In fruits having a dry pericarp, the concentrated state of the carbon preserves the fallen seeds from decay, till the embryo is called into action by the warmth of spring.

GERMINATION.

174. The germination of a seed is the change of the inert, and apparently lifeless embryo, into a living plant; and this is effected by the influence of heat, air, and moisture, which both excite the vital action of the embryo, and change the albumen of the seed into food proper for its support.

175. *Seeds cannot germinate* if any one of these three agents of heat, air, and moisture, be wanting. Seeds in the bed of an Italian river, where, of course, they had abun-

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184. What agencies contribute to germination of seed?
185. Effect of the absence of either of these agents.

dance of heat and moisture, were known to lie there more than fifty years perfectly inert, and yet to germinate as soon as they were exposed to the air, by being thrown with the mud of the river on the banks. Heat and air, without moisture, will dry seeds, and air and moisture, without heat, will rot them; but in neither case will they vegetate. Light, instead of being favourable to the development of the embryo, seems rather to retard it, and seeds are found to germinate readily in darkness.

176. *When the seed of an exogenous plant is put into the ground*, so as to exclude the light, but not the air, and supplied with heat and moisture, the combined effect of these three active agents will distend the particles of which the seed is composed, till it becomes so much enlarged that the outer covering cracks, and a small portion of the embryo appears projecting through the *foramen*. The period that elapses between the time when seeds are placed in a situation favourable to their development, and the time of germination, varies considerably. For example, the common cress germinates in two days, the turnip in three, grasses in eight, hysop in a month, many pines in a year, and the hazel not until two years.

177. *When germination has taken place*, a supply of food is necessary to form new cellular tissue; and it is on this account that nourishment is laid up in the seed, as the young plant cannot obtain food either from the ground or the air till its roots and leaves be developed. It cannot, however, at first avail itself of this provision, as its vessels can only take up liquid food, and neither starch nor gluten are soluble in water. To obviate this difficulty, as soon as the particles of which the seed is composed begin to be distended by heat, the seed absorbs water, and this being decomposed by the greater attraction of the carbon contained in the seed for the oxygen of the water, carbonic acid is formed. It is supposed that this carbonic acid combines with the nitrogen in the gluten of the seed, and produces a sweet substance called *diastase;* which, combining

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186. Describe the process and period of germination.
187. How is the young plant nourished?

with the remainder of the carbon, changes it into sugar. The young plant is thus furnished with all the nourishment it requires; the carbonic acid gas is dissolved in water and taken up by the spongioles, and the sugar is dissolved by the ascending sap in the sweet juice which is always found at the base of the growing part of a plant. As a considerable quantity of water is necessary to dissolve this sugar, and carry it upwards, more water is always taken up by a growing plant than is actually wanted for food; and in the same manner an extra quantity of oxygen is required to keep the carbon in a soluble state during its passage upwards.

178. *All seeds become sweet* during the process of germination, and it is in this manner that barley is changed into malt. The seed of the barley is moistened, and exposed to the influence of heated air in the kiln, till the embryo begins to grow, when its further progress is checked by putting it into the dry kiln, by which means the sweetness is retained, and malt is produced.

179. *The plant being provided with nourishment,* begins rapidly to develope itself. First, from the part projecting from the foramen, which now becomes the collar, a taproot descends, throwing out on each side a great number of short fibrous roots, each terminating in a spongiole. The *plumule,* or ascending shoot, next rises from the collar,

Fig. 75.—Germination of Dicotyledonous and Monocotyledonous Plants.

expanding its cotyledons (*a* in fig. 75) long before its other leaves unfold. The plumule generally lies concealed be-

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188. What of barley and malt?
189. Describe the development of plants.

tween the cotyledons, from which situation it emerges when the cotyledons open, as shown in the common bean (fig. 76).

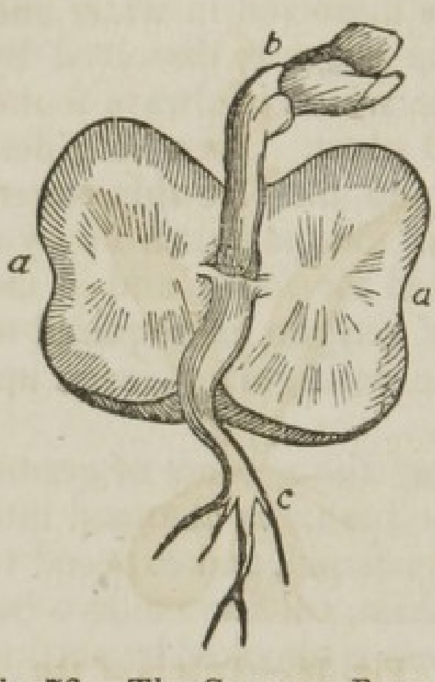

Fig. 76.—The Common Bean.

The sap now being exposed to the air, by passing through the numerous veins of the cotyledons, becomes enriched by the evaporation of its superfluous water and oxygen, and is changed into what botanists call the *descending*, *arterial*, or *vital sap*. In this state the sap consists only of carbon and water, or, to speak more correctly, of carbon combined with oxygen and hydrogen, in the proportions in which those gases are found in water; but from this four distinct substances are formed by the wonderful alchemy of nature, which are deposited by the proper juice to meet the wants of the growing plant. These four substances are starch, sugar, gum, and lignine; all of which, though apparently so different in their natures, are composed of carbon and water; and, strange to say, almost in the same proportions.

180. *Cotyledons are never found on young plants, unless these are raised from seed.* In such as are raised from bulbs, corms, and tubers, growth is merely the development of a bud. The bulb gradually wastes away as its store of albuminous matter is exhausted, and a new one forms in the axils of its leaves by its side. In a corm the same wasting away takes place, but the new corm is found above the old one, as in the crocus (see *a* in fig. 77). Tubers disappear in the same manner, but a distinct new tuber is formed by the side of the old one. Thus, if the root of the common orchis be examined while the plant is in flower, it will appear to have two tubers (see fig. 78); though, if the same plant be re-examined after the seeds have ripened, only one

190. Name the four proximate principles.
191. What of cotyledons?

tuber will be found; the old one (*a*) having wasted away—its place being supplied by the new one (*b*). The analogy

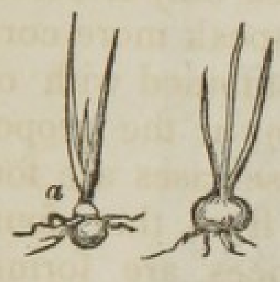

Fig. 77.—Germination of Bulbs and Corms.

Fig. 78.—Tubers of the Orchis.

between bulbs and buds is still further proved by the fact, that many plants bear bulbs in the axils of their leaves. Every bud is also a separate plant, which will grow like a bulb when put into the ground; this the gardeners call *striking by eyes*. *Budding* is on the same principle, only the bud is inserted into the sap-wood of another plant, and not into the ground.

181. *In monocotyledonous plants,* raised from seed, the radicle, when it projects from the seed, is enfolded in a covering called the *coleorhiza,* or root sheath (*c* in fig. 75). When the sheath has attained a considerable length it splits asunder, and from this opening arises the plumule (*p*), while the radicle (*r*) descends into the soil.

182. *Acotyledonous or cryptogamous plants* have no cotyledons, as the spores by which they are propagated are not seeds, but minute plants, which enlarge directly by the addition of new tissue. But of these curious forms of vegetation in another section.

FRUCTIFICATION OF FLOWERLESS PLANTS.

183. THE FRUCTIFICATION OF FLOWERLESS OR CRYPTOGAMOUS PLANTS is very remarkable, and quite different from that of flowering plants. They have neither flowers nor seeds, but are propagated by little embryo plants, called *spores*, or *sporules*.

184. *In the ferns*, or *filices*, which are the largest of the flowerless plants, little brown spots, called *sori*, may be observed on the backs of the leaves (see fig. 79). Each of

Fig. 79.—Ferns, showing the Sori on the back of the Fronds.

these is composed of a number of minute membranous capsules, termed *thecæ*, which contain the reproductive sporules. The thecæ are either sessile or pedicellate, being in the latter case surrounded by an elastic ring, which aids in bursting asunder the membrane, and dispersing the spores. Sometimes the sori originate under the epidermis of the leaf, forming minute protuberances; the portion of cuticle covering each sorus being called its *indusium*.

185. *Ferns are plants* generally consisting of a number of leaves, attached by tough fibrous petioles to a subterranean stem, the fronds being the only visible portion of the plant. In some varieties, however, the stem rises above

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192. What of flowerless plants?
193. Define the italicised technicals.
194. Describe the ferns.

ground to the height of forty or fifty feet, forming the well known *tree-ferns* of New Zealand and Van Diemen's Land (see par. 85, fig. 19).

186. *The equisetaceæ*, or *horsetails*, have their thecæ on the points of the bracteated spikes, which are placed in rings round the stem (see fig. 80). In the thecæ are slen-

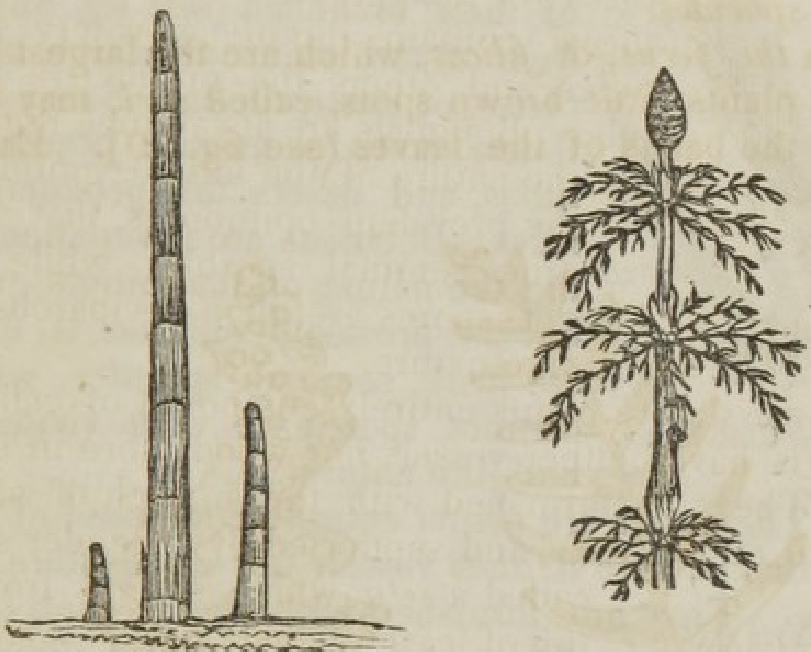

Fig. 80.—Equisetaceæ, Simple and Branched.

der elastic bodies, thickened at the end, called *elaters*, which are attached to the sporules, and at first rolled round them, but which open with a jerk, making the sporules appear to jump as if alive. The equisetaceæ are herbaceou sperennial plants, having hollow striated stems; these being either simple or branched, and jointed at intervals.

Fig. 81.—Pillwort.

187. *The marsileaceæ*, or *pillworts*, are aquatic herbs, which have ball-like receptacles at the base of their leaves (see fig. 81), containing the sporules and other minute granules supposed by some to be spores

195. What other plants are named, and their peculiarities?

in an undeveloped condition. The receptacles are always attached to leaves situated near one of the roots.

188. *The lycopodiaceæ*, or *club mosses*, which are intermediate in appearance between the true mosses and ferns, have bracteated spikes, like small fir cones, at the end of their branches (see fig. 82), at the base of the scales of which are their *thecæ*, or *conceptacles*. Some of these thecæ contain minute powdery granules, and others the productive sporules. Botanists are at variance regarding the nature of the minute granules; but the prevalent opinion is, that they are true seminal sporules, while the distinct spores are of a viviparous or bud-like nature.

Fig. 82.—Club Moss.

189. *The mosses* are plants entirely composed of cellular tissue—that is, have neither vessels nor woody fibre in their structure. They are furnished with thecæ, each of which is urn-shaped, and solitary, and supported by a slender stalk called a *seta*, which springs from a tuft of leaves called the *perichætium*. Each theca is covered by a small conical cap called the *calyptra*, or veil (see fig. 83. *a*), which is pushed off by the expansion of the theca when the sporules are ripe. If the calyptra be entire when it falls off, it is called *mitral;* but if it open first on one side, it is called *dimidiate*. The mouth of a theca is called its *stoma*, and is closed by a little lid, or *operculum*. The stoma is generally surrounded by a fringe of hair, called the *peristoma;* and when this is in two rows, the inner hairs are the *teeth*, and the outer ones the *cilia*. The cavity of the theca is called the *sporangium*, and in the centre is the *columella*, or axis. Sometimes the lower part of the theca is solid, when it is called the *apophysis;* and when this is

Fig. 83.—Moss.

196. Name the various mosses, and their peculiarities.
197. Define the technicals.

swollen on one side, it is said to be *strumose*. Besides their thecæ, mosses have other reproductive organs called *staminidea*, which partake of the nature of buds.

190. *The characeæ*, or *stoneworts*, have globules in the axils of their leaves, filled with a mucilaginous fluid, in which are numerous convoluted filaments, and minute spherical particles, or *nucules*, resembling buds, from which the young plants are raised. These plants grow under water, and their slender transparent stems are sometimes found incrusted with stony matter; hence the term *stoneworts*.

191. *The hepaticæ*, or *liverworts*, are small creeping plants, having their leaflets imbricated over each other, differing from the mosses in the form of the capsule. Their organs of reproduction are globular bodies, containing a minutely granular substance, escaping by an aperture; or they are capsules, containing sporules and spiral filaments, covered at first by a calyptra, at length rising on a peduncle, and opening by valves (see fig. 84).

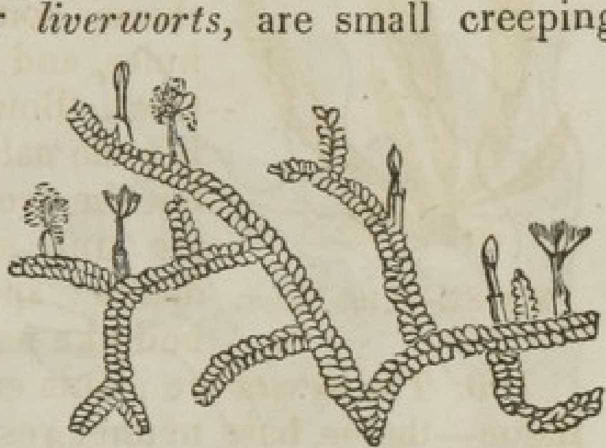

Fig. 84.—Liverworts.

Fig. 85.—Lichens showing their Reproductive Organs.

192. *The lichenes*, or *lichens*, vary exceedingly in form and texture, and comprise all those scaly ash-coloured substances

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198. What of the stoneworts and liverworts?
199. Describe the lichens, and their organs.

which grow on rocks, old walls, trunks of trees, &c. They may be said to consist of lobed fronds, or *thalli*, of a leathery texture, on the surface of which the reproductive matter appears in powdery or gelatinous expansions. The reproductive organs assume two common forms; *soridia*, or heaps of pulverulent granules scattered over the upper surface of the thallus; or *apothecia*, which are small cup-like specks, surrounded by a rim, and containing *asci*, or tubes, filled with sporules (see fig. 85).

193. *The algæ* are all strictly aquatic plants, growing either in salt or fresh water. By far the greater number of algæ inhabit the ocean; hence the general term *sea-weed* has been applied to this class of vegetation. They are destitute of leaves, properly so called, and consist of fronds of various forms, being either globular, filamentary, capillary, tubular, or laminar; and these again being either branched, continuous, or articulated. They are reproduced by sporules, contained in *sporidia*, which are usually situated in the substance of the plant, (see fig. 86).

Fig. 86.—Bladder-Wrack (*Fucus vesiculosus*); *a*, Vesicles containing the Spores; *b*, Section of the same.

194. *The fungi*, or *mushroom tribe*, which constitute the lowest forms of vegetable development, are extremely diversified in their size, shape, colour, and consistence. They are entirely composed of cellular tissue, and some are even apparently animated; so that they are regarded as connecting links between the vegetable and animal kingdoms. The

200. Name the varieties of sea-weed.
201. What of mushrooms?

Agaricus campestris, or common field-mushroom, is one of the best known, and forms the type of the family; but the mould on cheese, stale bread, the mildew on trees, the rust on corn, and many other minute and yet unobserved appearances of a similar nature, are all fungi. They have no fronds or leaves; and are hence termed *aphyllous*. Their organs of reproduction consist of sporules, lying loose on the tissue of the plant, or collected in certain places, which are distended by their aggregation. Figure 87 exhibits some of the most familiar forms of the fungi.

Fig. 87.—Agaricus Volvaceus (1), and Campestris (2).

195. *The manner in which the reproductive organs of flowerless plants perform their functions* is as yet but little understood by botanists. "We are entirely ignorant," says Professor Lindley, "of the manner in which the stems of those that are arborescent are developed, and of the course taken by their ascending and descending sap—if, indeed, in them there really exist currents similar to those of flowering plants; which may be doubted. We know not in what way the fertilizing principle is communicated to the sporules or reproductive grains; the use of the different kinds of reproductive matter found in most tribes is entirely concealed from us. It is even suspected that some of the simplest forms (of algæ and fungi, at least) are the creatures

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202. What link of the scale of being are these regarded?
203. What is known of the reproductive or vital organs of flowerless plants?

of spontaneous growth; and, in fine, we seem to have discovered little that is positive about the vital functions of those plants, except that they are reproduced by their sporules, which differ from seeds, in germinating from any part of their surface, instead of from two invariable points."

PHENOMENA OF VEGETATION.

196. *In addition to the ordinary functions of the organs,* which are the same in all plants of the same genus, there are certain anomalous functions which cannot be reduced to regular laws, and which differ in different species even of the same genus. The most remarkable of these are the occasional *irritability* of plants, their *colours, fragrance,* and *tastes.*

IRRITABILITY, AS DEPENDENT ON ATMOSPHERIC INFLUENCE, ON CONTACT, AND ON INTERNAL EXCITATION.

197. THE IRRITABILITY of animals depends entirely on their nervous system; but as plants have no nervous system, their irritability is more difficult to be accounted for. Dr. Darwin, indeed, asserts that plants are only an inferior kind of animal, and that they, or at least some of them, have a brain and a stomach, and are endowed with the lower senses. According to this fanciful doctrine, the medulla or pith was made the seat of sensation, and was considered analogous to the spinal marrow of animals. The doctor, however, had no followers, as his hypothesis presented too many difficulties to be even partially believed.

198. *The principal phenomena* of vegetable irritability may be divided into three kinds; namely, those caused by atmospheric influence, those depending upon the touch of other bodies, and those which appear to be perfectly spontaneous.

199. *Atmospheric influence occasions the closing of the leaves over the extreme point of the young shoot at night,* as

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204. What phenomena of plants are named?
205. How is irritability accounted for?
206. Examples of atmospheric influence.

may be observed in the chickweed and several other common plants. The folding of some flowers in the absence of the sun, and the opening of others as soon as that luminary has withdrawn its beams, are ascribable to a similar cause. The white marigold closes its flowers on the approach of rain, and the dwarf calendrina folds up its bright crimson corolla about four o'clock every afternoon. The evening primrose, on the contrary, will not open its large yellow flowers till the sun has sunk below the horizon; and the night-blowing cereus only expands its magnificent blossoms about midnight. Some flowers are so regular in their hours of opening and shutting, that Linnæus formed what he called *Flora's Time-piece*, in which each hour was represented by the flower which opened or closed at that particular time. Thus—tragopogon pratense opens from three to five; papaver nudicaule at five; hypochæris maculata, six; nymphæa alba, seven; anagallis arvensis, eight; calendula arvensis, nine; arenaria, nine to ten; and mesembryanthemum at eleven.

200. *Solar light is the principal agent in producing these phenomena;* but, in some cases, flowers have been known to open by artificial light. De Candolle found blossoms expand beneath a lamp nearly as well as beneath the sun itself; and the crocus-flower, which closes at night, has been known to expand as wide as possible when gently exposed to the light and heat of a fire. Besides the cases in which flowers open and shut their corollas by the influence of light, instances are known in which merely the petals roll up by day, and resume their natural shape after sunset, as in some of the silenes.

201. *The sleep of plants*, a term first proposed by Linnæus, is a very remarkable phenomenon. In compound leaves, the leaflets fold together, and the common stalk droops; while in other cases—as, for example, in the chickweed—the leaflets fold over the bud of the young flower, as if to protect it from injury from either the cold of night

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207. What of Flora's Time-piece?
208. The effect of solar light.
209. What is the sleep of plants?

or the heavy dews of early morning, though no movement is observable in these plants at any other period. One of the most remarkable circumstances respecting the effect of atmospheric influences is, that the same causes do not affect all plants, and yet no peculiarity of construction has been discovered in those that are so affected to distinguish them from those that are not.

202. *The irritability produced by external touch* is a familiar but little understood phenomenon. The movements of the sensitive plant are well known; and it is also known that if the ripe seed-vessels of the noli-me-tangere be touched in the slightest manner, they will open with elasticity, and scatter their contents. In the same manner the fruit of the squirting cucumber throws out its seeds and the moist pulp in which they are contained, with great violence, and to a considerable distance. The stamens of the barberry, when touched with a pin, spring forward, and appear to make a bow to the stigma, after which they return to their proper position; while the column of the stylidium, which includes the style and stamens, and which generally hangs on one side, when touched, springs with a jerk to the other side of the flower. The anthers of the kalmia appear to be fastened back by notches in the petals, and when liberated by insects or other means, they become erect, and do not return to their former position.

203. *The most remarkable instance of irritability by contact* is that exhibited by Venus's fly-trap, ***Dionæa muscipula,*** a native of Canada, and nearly allied to the common sun-dew of the British commons. Its flowers have nothing remarkable about them, except that their petals roll up when they are about to decay; but the leaves are very curiously constructed. They have broad leaf-like petioles, at whose extremity are two fleshy lobes, which form the real leaf, and which are armed with strong sharp spines, three on the blade of each lobe, and a fringe of longer spines round the margin (see fig. 88, 1). When an insect touches the base of the central spines, the leaf collapses, and the poor

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210. Name instances of the effect of touch.
211. What remarkable instance is named? and another?

insect is caught, being either impaled by the central spines, or entrapped by the others. The leaf then remains closed, the fringe of long spines being firmly interlaced and locked together, till the body of the insect has wasted away. This apparatus being the nearest approach to a stomach which has been yet observed in plants, an experiment was tried some years ago of feeding a dionæa with very small particles of raw meat, when it was found that the leaves closed in the same way as they would have done over an insect, and did not open again till the meat was consumed. Saracenia, or side-saddle flower, the leaves of which have a pitcher-shaped petiole (fig. 88, 2), also decomposes flies and other insects caught in the pitcher—a peculiarity which seems to belong to all plants having pitcher-shaped leaves.

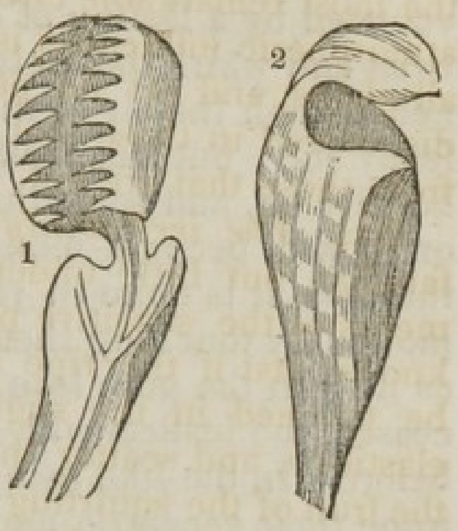

Fig. 88.—1, Leaf of Venus's Fly-Trap; 2. Leaf of Saracenia.

204. *The spontaneous movements of plants* are much more difficult to be accounted for than those occasioned by atmospheric phenomena, or by external touch. We can fancy light and heat contracting or dilating the vessels, and thus occasioning flowers to open or shut, and leaves to fold or unfold; but plants have some movements for which there is apparently no external cause. Among these spontaneous movements, however, those are not reckoned which belong to growth. It is true that the leaves elongate, the flowers expand, the anthers burst, and the seed-vessels open spontaneously; but these are movements caused by the progressive development of the plant, and subjected to regular laws. The spontaneous movements which arise from irritability are quite different—as, for example, those of the leaves of *Hedysărum gyrans*. This plant has compound leaves, the terminal leaflet of which never moves except to fold itself close down to its own stalk; but the side leaflets

212. Are any moved spontaneously?

have such eccentric movements, as to render it difficult, if not impossible, to explain them, and which might appear, indeed, to a fanciful mind as though the whole plant were actuated by a feeling of caprice. Generally, all the leaflets twist and whirl themselves about in an extraordinary manner, though the air of the house in which they grow is perfectly still; but frequently the leaflets on only one side will be affected, and sometimes only a single leaflet will move, or all will become motionless together; and when this is the case, it is quite in vain to attempt to set them again in motion by touching them; though sometimes in a moment, as if from the pure love of mischief, after the touching has ceased, the leaflets will begin to move again as rapidly as before. In the like manner the side leaflets frequently continue their eccentric movements all night, while the terminal leaflet remains quietly folded up, and apparently fast asleep. Cold water poured upon this plant stops the motion of the leaves, but it is renewed as soon as the heat of the stove in which the plant grows has converted the water into vapour.

205. *Movements analogous to those of the Hedysàrum* and other foreign plants have been detected by M. Dutrochet in several common vegetables, such as the garden pea and cucumber. As soon as the fourth leaf above the cotyledons of the pea was developed complete with the simple point which terminated its petiole, he remarked in this point, and in the leaf itself, peculiar revolving slow movements. He attributes them to an interior and vital excitation, and not at all to the action of light, which is opposed to, and, if vivid, arrests them.

206. *Plants may be deprived of their irritability* by keeping them without water, when they become flaccid; or by watering them with a poisonous liquid, in which case they lose not only their irritability but their lives. Life, indeed, appears to be intimately connected with irritability, as the latter quality exists only in plants in a vigorous and healthy condition.

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213. Do not these seem to depend on temperature?
214. Modes of destroying irritability.

207. *The vitality of plants may be destroyed by giving them deleterious or poisonous substances.* These facts have been established principally by the experiments of Marcet and Macaire. Common kidney beans which had been watered with a decoction of arsenic faded in the course of a few hours; they then began to turn yellow, and on the third day were dead. A lilac was also killed by having arsenic introduced into a slit in one of its branches. Mercury, under the form of corrosive sublimate, produced the same effects as arsenic; but when used as quicksilver, no results were observed. Vegetable poisons have been proved to be equally injurious to other plants as mineral ones; a solution of nux vomica killed some kidney beans in the course of a few hours. Prussic acid had the same effect in the course of a day, and deadly nightshade in about four days; while spirits of wine killed the plant to which it was administered in a few hours. The conclusions drawn from these experiments were—first, that mineral poisons act upon vegetables in nearly the same way as they do upon animals—that is, they destroy the vessels by their corrosive influence; and secondly, that those vegetable poisons which kill animals by acting upon their nervous system, also destroy plants, though they have no apparent nervous system to be acted upon.

208. *The functions of vitality in plants may be suspended without destroying life*, by administering to them the same substances which produce stupor in animals. For instance, a barberry bush watered with a strong decoction of opium lost the power of moving its stamens when touched; and a dionæa entirely lost its fly-catching powers. Many other curious experiments on the vital functions and phenomena of plants might be mentioned, but they are chiefly of the same nature as the above, with nearly the same results.

COLOUR—CAUSES AND LIMITS OF.

209. THE COLOUR OF PLANTS generally depends on the presence of a substance called *chromule*, which is deposited

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215. What of poisoning of plants?
216. Upon what does colour depend?

in minute granules in the vesicles of the cellular tissue. This substance consists of pure carbon, which has been *fixed*, as physiologists term it, by the decomposition of the carbonic acid gas absorbed by the plant; the oxygen escaping again into the atmosphere, while the carbon is permanently assimilated. Both the absorption and decomposition of carbonic acid take place most effectively under the influence of solar light; hence, plants grown in darkness become etiolated, or blanched. The exclusion of light has also the effect of rendering them mild and succulent, as the water taken up by the roots is prevented from evaporating, and their peculiar products cannot be secreted without a due proportion of carbon. Acrid and even poisonous vegetables may be rendered wholesome, or at least harmless, by earthing them up so as to exclude the light.

210. *The chromule in all plants being the same*, it is difficult to explain why leaves should be green, and flowers of so many varied hues; indeed, the cause is as yet but very imperfectly understood. It is found, however, that when the leaves first expand, and are of the brightest green, the grains of chromule are always surrounded by a thin film of gluten, the principal ingredient in which is nitrogen. In autumn, the gluten and carbon generally have both disappeared, particularly in plants which contain a notable amount of acid, the basis of which is oxygen. In proportion as the oxygen predominates, the leaves become red; hence the beautiful tints of red and crimson taken by some leaves in autumn. When the carbon disappears without the nitrogen, as is frequently the case, the leaves become yellow in autumn. It has been observed that the leaves of plants always turn yellow, red, crimson, or violet, and never blue; and this corresponds with the above theory, as the carbon, which is dark, is carried out of the leaves by the descending sap, and its place partially supplied by oxygen. Thus, red, which is the colour produced by oxygen, predominates in decaying leaves; and violet, which implies a mixture of carbon, is only found in the dying leaves of the

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217. What of the privation of light?
218. Upon what does the varieties of colour depend?

American white oak. The lime, and other trees which abound in mucilage, or gluten, further corroborate this theory, in having their decaying leaves yellow.

211. *In all cases the colouring matter is not in the sap*, which is either colourless, or tinged faintly with yellow, but in the cellular tissue; and thus, while the stem consists chiefly of cellular tissue, it is as green as the leaves.

212. *The colours of flowers* are more difficult to be accounted for than those of leaves, as they are evidently influenced by the soil in which the plants are grown, more than by solar light. Mineral substances, particularly iron and manganese, are found abundantly in white flowers when burned; and it is known that many a common British weed, particularly the herb Robert, varies from a dark rose colour to almost white, according to the soil in which it grows. Flowers grown in the shade are, however, seldom different in colour from those fully exposed to the air and light. The petals of the common butter-cup, and the lesser celandrine, are of as brilliant a yellow in town gardens enveloped in the smoke of London, as on any country hill; and roses always maintain their brilliant tints, even when the bushes on which they are produced are evidently dying for want of a clear atmosphere.

213. *Flowers may be made to change their colours* by the influence of the soil in a most remarkable manner. The flowers of the common hydrangea, which are naturally pink, may be made blue by planting the shrub in soil impregnated with iron. The change produced in tulips is still more extraordinary; the flower of a seedling tulip is generally of a dull brownish crimson, and after remaining of this colour two or three seasons, it will suddenly *break*, as the florists term it, into the most brilliant and varied tints of rose white, yellow, brown, or purple, without leaving any trace of the original colour. In order to produce this change, florists try a variety of means, all of which have relation to the soil; for example, they sometimes keep their tulips in poor soil, and then suddenly transplant them into one ex-

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219. The effect of soil upon flowers.
220. Experiments upon flowers, and their colour.

ceedingly rich, or they reverse the process; at other times they change them suddenly from a sandy to a clayey soil. Carnations also become striped and variegated by planting in rich soils, though they have all originated from the dark crimson clove. The colours of heart's-eases are improved in the same manner; and it is a very striking fact, that all these variegations will degenerate, or *run*, as it is called, if the plant be neglected, and suffered to remain in soil the richness of which has been exhausted.

214. *As a further proof that light is not the sole cause of colour in plants*, it is well known that ferns and mosses have been found green in mines where they have grown in total darkness; and green and red sea-weeds of the most brilliant tints are frequently washed up from the bottom of the sea, where the light, being weakened by passing through such an immense body of water, can have but little effect in producing colour.

215. *The theory, or rather hypothesis, of the Xanthic and Cyanic series of colours* was first broached about the year 1825, by Messrs. Schübler and Funk. These botanists supposed that there are two series of colours which never mix with each other. The first of these, which they called the Xanthic series, contain only such colours as are composed of some shade or combination of red or yellow; and the Cyanic series, in the same manner, only of such as contain some shade or combination of red or blue. Green is equally divided between the two series, bluish-green being included in the one series, and yellowish-green in the other. According to this theory, it was supposed that, in all the variations of plants, the one series never ran into the other; in other words, that no genus contained species some of which have perfectly blue flowers, and others perfectly yellow. Thus, De Candolle, and other botanists, have asserted that it is impossible there can ever be a blue dahlia or a blue rose.

216. *Experience, however, has shown this hypothesis to be*

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221. Proofs that light is not the sole agent.
222. Curious theory lately broached.
223. Objections to it.

incorrect; as the blue tropeoleum and the blue lichtenaultia both belong to genera the flowers of which are usually red or yellow. Many other examples might be named, such as the campanulas, the lobelias, and the anemones, some species of which are of a pure brilliant blue, while others are of as brilliant a yellow; and these two colours are occasionally found perfectly pure and brilliant in the same flower—as, for example, in the beautiful Californian annual, *clintonia pulchella.* White, which is always called a colour when speaking of plants, was supposed by the same botanists to be caused by the emptiness of the cells of the tissue; but this cannot be the case: as, were the cells empty, it would not make the petals white, but what botanists call *herbaceous* or colourless—that is, of a pale yellowish-green. Besides, white flowers generally change more or less when they are dried; some become blue, others yellow, and others of a reddish tinge. Blue flowers generally turn red when they are decaying, but red and yellow ones seldom change when dried, except merely to assume a more dingy hue.

217. *Some flowers progressively change their colours* when they are in a living state—as, for example, the flowers of the cobœa are first yellowish-white, then greenish, and lastly purple; the flowers of the anothera tetraptera are first white, then pink, and lastly crimson; and those of the beautiful ipomœa rubrocœrulea, which are first blue and then pink.

218. *The colouring matter extracted from vegetables is of great economical value,* being extensively used in the art of dyeing. Some of these dyes, to be afterwards noticed (par. 250), are the same with the natural colour of the parts from which they are derived; such as saffron, which is the yellow stigma, of a species of crocus; but others are totally dissimilar, being blue or black, when the native vegetable texture is green.

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224. Changes of colour in flowers.
225. Usefulness of colouring matter of flowers.

FRAGRANCE—PERMANENT, FUGITIVE, AND INTERMITTENT.

219. *The causes of fragrance in flowers* have never yet been fully explained. We know that all organized bodies consist partly of volatile matters, and thus we can readily account for the odours given out by decaying animal and vegetable substances, as they evidently proceed from the volatile parts being liberated by decomposition. The fragrance of flowers, however, escapes while the plants are in a living state, and that most abundantly when they are in vigorous and healthy condition. Besides the flowers, other parts of living plants frequently exhale fragrant odours, such as the leaves of the myrtle and geranium, and the wood and bark of pines. All these odours proceed from oily or resinous matters contained in the receptacles of secretion; but the laws that regulate their liberation are yet only imperfectly known. As a proof of the uncertainty which prevails on the subject, it may be mentioned, that when the Academy of Sciences at Brussels proposed it as a prize question in 1838, no essay was sent in; and that when the question was repeated in 1839, only one answer was received. This essay was written by Signor Trinchinetti, formerly professor at the university of Pavia; and though it obtained the silver medal, it has not thrown much light upon the subject.

220. *The physiological uses of odours* are by no means certain. Some botanists consider them to be part of the excrementitious matter which is thrown off by plants, when it is no longer necessary to their growth; but if this were the case, the exhalation would continue the same during the whole period of growth, and not vary, as it does, at different seasons, and according to the state of the weather. It is well known that plants are most fragrant in damp weather, and some botanists have attempted to account for this by supposing, that the tissue being relaxed at such seasons, the stomata, or pores, open wider than at other times, and thus permit the escape of a greater quantity of the fluid.

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226. Varieties in fragrance of flowers.
227. How is fragrance explained?

Trinchinetti, however, thinks that the use of the odours of flowers is to ward off vapour, which might prevent the diffusion of the pollen; and it is thus that he accounts for the increase of the odour by damp. This explanation appears plausible, but neither it nor any of the others which have been suggested, will explain why the petals of roses, and other flowers, retain their fragrance when dried. The use of fragrance in leaves, bark, and wood, is apparently to preserve them from the attacks of insects; as we find that the smell of the red and Bermuda cedars, of which pencils are made, and of camphor (also a vegetable product), are sufficient to keep the moth from attacking substances with which these are in contact.

221. *The odours of plants are of three kinds*—permanent, fugitive, and intermittent :—

222. *Permanent odours* are those given out slowly by the plant, not only whilst it is living, but also after the fragrant part has been separated from the root, though it be not in a state of decay. Of this kind are the odours of fragrant wood, of the dried petals of roses, and some other flowers. In these cases the receptacles of secretion are generally buried so deeply in the tissue, that the essential oil with which they are filled can only escape slowly, and in very small quantities. In some cases, indeed, the receptacles of secretion are so deeply seated, that the wood to which they belong appears devoid of scent, till its essential oil is volatilized by exposure to heat. Thus, the wood of the beech appears inodorous till warmed by the friction of the turner's lathe, when it acquires a smell like that of roses. In a few instances, where the wood is light and of open texture, the odours are not permanent—as, for example, in the pine and fir tribe. Every one who has entered a grove of these trees in the evening, when the dew was falling, must have been struck with the fine balsamic fragrance given out; and yet none of this fragrance is perceptible in the wood of the same trees when it has been cut up into deal, and used in the floors and wainscoting of a dwelling-house.

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228. Theories concerning its utility.
229. What of permanent odours?

223. *Fugitive odours* arise from essential oils contained in receptacles just below the epidermis; and when there is only a minute quantity of oil in each cavity, the duration of the fragrance is correspondingly short. Odours of this kind are generally found in flowers, and their intensity is much increased by a damp state of the atmosphere, as, according to Signor Trinchinetti, the odour of the flower is then most needed to protect its reproductive parts.

224. *Intermittent odours* are the most difficult to be accounted for by the vegetable physiologist. It is only known that the night-smelling stock, the Indian jasmine, and several other plants, which are entirely devoid of scent during the day, are delightfully fragrant during the night. One of the orchideous plants produces its powerful aromatic scent only when exposed to the direct rays of the sun; and the night-blowing cereus is fragrant only at intervals of about half an hour during the time of its expansion, preserving the same kind of intermittence even when separated from the stem. Some botanists have supposed that intermittent fragrance is occasioned by the respiration of plants, but this cannot be the case in a flower whose vitality is extinct.

TASTES—INFLUENCES WHICH MODIFY.

225. *The tastes produced by vegetable substances* are generally recognised as sweet, acid, bitter, astringent, austere, or acrid. The juice of the sugar-cane, for example, is sweet, that of an unripe apple acid, the aloe bitter, the leaf of the bramble astringent, and the cranberry austere. It has been already stated, that the ascending sap is at first insipid, and that it gradually acquires the peculiar taste of the plant; but it is only in the descending juice that the taste-yielding principle is fully developed. Why the taste of one vegetable should differ from that of another, physiology is unable to determine; it cannot tell why rhubarb, beet-root, and tobacco, grown in the same soil, and sub-

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230. What of fugitive odours?
231. Mystery of intermittent odours, examples.
232. Varieties of taste, their cause.

jected to the same influences, should be so different in their respective qualities. We are only as yet able to characterize the various tastes of plants, and understand some of the chief causes by which they may be modified or destroyed.

226. *The principal influences which modify the tastes of plants* are atmospheric and solar; light, exposure and warmth, being those under which taste, as well as all other qualities of vegetables, are most fully developed. Every one is acquainted with the blanching effects of *earthing*, as exhibited in celery, or in the shoots of the common rhubarb. The fruits grown in our own island during a wet and sunless season are insipid, compared with what they are in a dry and bright summer; and the general vegetation of the arctic and temperate regions is less powerful in kind than that of the tropics. Even the successive periods of a day exercise an influence on the tastes of growing plants (par. 10), according as they are stimulated by solar light to absorb or exhale oxygen—the principle on which the peculiarities of taste greatly depend. Soil, though it does not produce taste, is yet capable of modifying it to a certain degree, as takes place every season with our cultivated vegetables; the potato, carrot, or turnip, grown on soft spongy land, being less sapid than those raised on light and dry situations. As a general law, it may be stated, that the drier and warmer the situation, the more exposed to light, and the slower the growth of any vegetable, the more intense its peculiar flavour.

227. *Vegetable membrane is insipid;* so also are resins and other insoluble products. Mucilage communicates no flavour; and it is only in the secretions and the extractive products that taste seems to reside. The peculiar tastes of vegetables may be described as a variable quality, for many are sweet, acid, or even acrid, at successive stages of their growth; a familiar example being afforded in the ripening of our own domesticated fruits. The acrid principle is generally found to reside in volatile oils; and bitterness always denotes the presence of extractive matter.

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233. How modified?
234. Changes of taste in the same fruit.

The sweetness produced during the germination of seeds, and the subsequent tastes acquired by a plant as it advances to maturity, are the result of vitality. The tastes and flavours produced in all vegetable matter during fermentation is strictly a chemical process (see par. 237), and does not come within the province of the botanist.

228. *The physiological uses of the different tastes* are as imperfectly understood as the causes which produce them. Some of them may be given for the preservation of the vegetable against the attacks of animals at certain seasons of its growth, whilst others seem as directly bestowed to render plants agreeable to the animals destined to consume them. We know that animals cannot subsist upon the inorganic matter of the globe; and that vegetables, from their power of decomposing and assimilating that matter, become the link of connexion between the animal and mineral kingdoms; hence it is not unreasonable to suppose that the different tastes of plants are conferred for the purpose of administering to the varied wants of animals—the flavour of each being best adapted to those wants, when the seed of the plant is perfectly matured.

MISCELLANEOUS PHENOMENA—LUMINOSITY, HEAT, ELECTRICITY.

229. *The luminosity of plants*—that is, the evolution of light either from living or dead vegetable structure—is a rare and curious phenomenon. Flowers of an orange colour, as the marigold and nasturtium, occasionally present a luminous appearance on still warm evenings; this light being either in the form of slight electric-like sparks, or steadier like the phosphorescence of the glow-worm. Certain fungi, which grow in warm and moist situations, produce a similar phosphorescence; and decaying vegetables, like dead animal matter, have been observed to emit the same kind of luminosity. This phenomenon seems connected with the absorption of oxygen, and the

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235. Theories concerning its utility.
236. What of luminous plants?

parts emitting it are the most luminous when immersed in pure oxygen, and cease to emit it when exluded from that element. Luminosity is sometimes occasioned by actual combustion of the volatile oils, which are continually flying off from certain plants: those of the dictamnus albus will inflame upon the application of fire.

230. *The evolution of heat* by living plants is a more common phenomenon. We are aware that warm-blooded animals have the power of keeping up a certain temperature within them, which varies at certain stages of their growth, and perhaps periodically. This result is obtained by respiration—the oxygen of the atmosphere uniting with the carbon of their blood, and producing a series of combustion. The carbonic acid and moisture which animals expire, prove that such a union has taken place. The more fresh air we breathe, the greater the heat of our bodies, so long as we take proper food to afford the carbon. A similar, though less understood phenomenon, seems to take place in the respiration of plants. Heat is always disengaged when gaseous products are liberated; and as vegetables respire (however slowly), a certain amount of heat must be produced during that process. In germination, heat is sensibly evolved: a piece of ice placed on a growing leaf-bud will dissolve, when it would remain unchanged in the open air; and experiment has proved that the surface of plants is three or four degrees higher than the surrounding medium. Again, the internal temperature of a large trunk is always higher than the surrounding atmosphere; and though young shoots are sometimes frozen through, the general structure both of the wood and bark is such as to conduct heat so slowly, that the internal warmth is never reduced beyond what seems necessary to vitality. Generally speaking, it may be asserted that plants possess an internal vital temperature, and that, in the process of respiration (the giving off of carbonic acid or oxygen, as the case may be), a certain degree of heat is always evolved. During germi-

237. Theories to account for it.
238. What is the source of heat in plants?
239. Analogy with respiration in animals.

nation and flowering, this heat is most perceptible; and though it be rapidly dissipated by the extent of surface exposed to the air, 110 degrees have been noted during malting, and 87 in the flower of a geranium when the atmosphere was only at 81.

231. *The connexion of electricity with vegetable growth* has recently excited the attention of physiologists; but little positive information has yet been ascertained. It has been long known that growth takes place with great rapidity during thundery weather; but this may result from the nitrogenised products of the showers which then fall, as well as from the effects of electricity. The progressive states of vegetable growth are the result of chemical changes; and as these changes are more or less accompanied by electricity, it is supposed that plants evolve electricity as well as heat. The conversion of water into steam is followed by a sensible evolution of electricity; and the evaporation which takes place from the surface of rapidly-growing leaves, produces the same phenomenon. The general electric state of plants is said to be *negative;* and some have attempted to connect the luxuriant vegetation of the tropics with the thunder-storms of these regions, on the supposition that when the atmosphere is *positively* electrified, the two opposite states will give rise to such commotions. [This theory acquires plausibility from experiments recently multiplied in Europe, and which have been repeated in America, by employing electricity in promoting the growth of seeds, plants, and flowers, the success of this new agent having developed results almost magical.]

SECRETIONS OF PLANTS.

232. Substances possessed of various properties are secreted by plants, according to their respective natures, and their healthy or diseased condition at the time of secretion. Some of these substances are produced by the ascending sap; but the greater number are deposited

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240. What of the influence of electricity?
241. How are vegetable secretions modified?

by the elaborated, or proper juice, and consequently are never secreted during spring or early summer. The intensity of those derived from the latter source depends in a great measure upon the influence of solar light; hence they are much stronger and more abundantly produced in tropical than in temperate climates.

233. *The physiological uses of these secretions* are at present but imperfectly understood. Most of them being derived from the true, or arterial sap, they would seem to serve some purpose in the reproduction or nourishment of the plant; but others, from the manner in which they are deposited or ejected, appear to be of no utility in the vegetable economy. Some of them are *excretions* as well as *secretions;* but whether they are to be considered as essential components of the sap, or evacuations necessary to the healthy condition of the secreting organs, has not yet been determined. Being exceedingly varied in their properties, they are of great utility to man, either as articles of food, clothing, medicine, ornament, or luxury.

234. *The economical applications* of vegetable secretions and excretions are so numerous, that in a work of this nature, it is possible merely to allude to the more important. It is even difficult to attempt any classification of them; for, though differing in their properties and external appearance, many of them are identical in chemical composition, and, subjected to peculiar treatment, readily pass into new and similar combinations. Some, for instance, are farinaceous, while others are saccharine; and yet both, when subjected to fermentation, produce similar liquors. Many are oleaginous, balsamic, or resinous; some are narcotic, aromatic, or mucilaginous; while others are astringent, purgative, or poisonous.

FARINACEOUS AND SACCHARINE PRODUCTS.

235. *Of the farinaceous products,* flour is, perhaps, the most important to man. That generally used in making

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242. Their physiological uses.
243. Their variety and economical applications.
244. Name the farinaceous products.

bread is the albumen of the seed of wheat, the epidermis being ground with it, and forming the bran. Meal is, in like manner, the albumen of oats, barley, rye, peas, beans, maize, and other grains. Starch is generally made from the flour of wheat, but sometimes from the farinaceous part of the potato tuber, which is otherwise extensively used as an article of food. The arrow-root, sago-palm, and several other plants, yield floury matter either from their seeds, piths, or fleshy tubers. In most of these cases the farinaceous product is stored up as nutriment to the future embryo, besides directly subserving to the support of the animal kingdom. The principal elements in the farinaceous products are starch, gluten, and albumen, with a slight proportion of oily and saline matters.

336. *Sugar* is another important vegetable product, alike essential to germination (see par. 177), and valuable to man. The ascending sap of all plants is sweet; but it is only in the sugar cane, the sugar maple, and the white beet-root, that sugar is elaborated in sufficient quantities to be of economical value. The sugar of commerce is chiefly derived from the sugar-cane and beet-root, by expression and evaporation. It is subsequently purified, when it crystallizes in a regular manner, the residue forming the dark viscous substance called molasses. Grape sugar, which is extracted from the grape, gooseberry, fig, &c. has a different taste, and contains more water.

237. *The fermented liquors* derived from vegetable products are numerous, and of various utility. Before detailing these, however, it may be useful to know that all vegetable matter is liable to certain states of fermentation, according to the degree of heat, air, and moisture to which it is subjected. These states have been successively described as the saccharine, vinous, acetous, septic, and bituminous. For example, the *saccharine* is that which manifests itself in the operation of malting (par. 178) and ripening of fruits; if water and heat be applied, it passes into the *vinous*, or that

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245. What are their proximate elements ?
246. Sources of sugar.
247. What are the varieties of fermentation ?

by which wine and spirituous liquors are formed. Again, if, while the vinous is going on, air be partially admitted, the *acetous*, or vinegar-forming fermentation will be produced; and by farther exposure of the vegetable matter to the air, it will pass into a mass of earth and carbon; this fits it for the *septic*, or putrefying process; but if air be excluded, if heat, moisture, pressure, &c. be present, the *bituminous* will be the result. By a knowledge of these processes, it is easy to understand how malt, wine, vinegar, vegetable mould, and coal, are formed.

238. *Wine, alcohol,* &c. are readily obtained wherever there is abundance of sweet juice in any vegetable product, as it is this sort of juice which is alone capable of fermentation. Wine is generally made from the juice of the grape, but it may also be obtained from the ascending sap of the maple and other vegetable productions. The best brandy is distilled from wine, but an inferior sort may be made from peaches, plums, and various other kinds of fruit, as also from the tubers of the potato when in a state of fermentation. Alcohol, ale, and other malt liquors, are derived from fermented grains, such as barley, oats, wheat, &c., but may also be obtained from potatoes. Arrack is distilled from the ascending sap of the palm tree. Rum is made from molasses; and Hollands is a corn spirit, flavoured with the berries of the juniper. Kirschwassa and maraschino are both distilled from cherries, cider from apples, perry from pears, and all the other kinds of *liqueurs* are obtained from vegetable products.

OLEAGINOUS PRODUCTS.

239. *The oleaginous products* are of two kinds; the *essential* oils which have been already mentioned (par. 223), the use of which in vegetation has not been positively ascertained, and the *fixed* oils, which supply the place of albumen in the seed. The essential, or volatile oils, are

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248. Describe these and their products.
249. Varieties of alcholic liquors, and whence obtained?
250. The different oils, and where found in plants?

chiefly found in the bark, leaves, flowers, and pericarps, and seem connected with the preservation and protection of the living plant. They are easily distinguished from the fixed oils by their powerful odour, their slight solubility in water, and the property of being volatilized without decomposition. They are the cause of odour in most vegetable products, and are consequently used in the arts principally as perfumes. The fixed oils occur in fruits and seeds, in which they serve both as a protection and nourishment to the future plant. They are combustible substances, insoluble in water, and form soaps with alkalies. By exposure to the air, some of them become opaque, and thicken, as almond oil; while others dry without losing their transparency, forming a varnish, as linseed oil. The economical applications of the fixed oils are very numerous, being used in food, in lighting, painting, &c. Olive, almond, linseed, rape, cocoa, and castor oils, are familiar examples; and it is worthy of remark, that they do not partake of the qualities peculiar to the other secretions of the plants from the seeds of which they are derived.

240. *Wax* is also a vegetable product, and differs from fixed oils only in being solid at common temperatures. Besides that collected and elaborated by bees from flowers, many plants yield it in a pure state. It is found in the form of minute scales on the surface of the plum and other fruits, and as a thin coating on the leaves of the cabbage and other plants, constituting what is called the *bloom*. It may also be obtained in small quantities from other plants, by the application of heat; but those yielding it in greatest abundance are the candleberry myrtle and the wax palm—both of which take their names from the circumstance. In the former it is found in the fruit, and in the latter it is laid over the leaves and trunk in the form of a varnish. In all cases the physiological uses of wax seem to be to protect the vegetable from the injurious effects of moisture; and so well adapted is it for this purpose, that the leaves of the

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251. The use of these oils.
252. What of wax, and where found?
253. Vegetable sources of wax, and its uses?

wax palm are used in South America for covering houses, and have been known even in this state to sustain the vicissitudes of weather for twenty years.

241. *A product resembling tallow* is obtained from the fruit of several plants, such as the croton schiferum of China, and the piney, which grows on the Malabar coast of India. In the croton, the fatty matter surrounds the stony kernels, and in the piney it is associated with the pulpy fruit. Like wax, vegetable tallow seems not only to protect the fruit, but to yield nutriment to the embryo plant; while both are largely used in the arts as a substitute for animal tallow.

242. *Camphor*, which is nearly allied to the volatile oils, is a solid, colourless, highly odorous, and inflammable substance. It exists in many plants, but is chiefly obtained from a species of sweet bay, growing in the East Indies. The branches and roots of this tree are cut into small pieces, and slowly boiled in iron vessels, the covers of which are made hollow, and stuffed with straw. Being volatile, the camphor rises with the vapour, and lodges in the straw, whence it is collected, and subsequently melted into lumps for sale. In old camphor-bearing trees, the camphor is sometimes found in small native concretions, occupying the place of the pith; but this variety is rare, and high priced. Unless as a protective, the physiological uses of camphor are not very perceptible. Economically, it is largely employed in medicine, in the preparation of varnishes, and in preserving specimens of natural history from the depredations of insects.

RESINS, GUMS, BALSAMS, &c.

243. *The resins, gum-resins, and balsams*, are a very numerous and valuable class of vegetable products. The resins are dry, brittle substances, insoluble in water, soluble in alcohol, fusible, and highly inflammable. The gum-resins are solid compounds of resin and gum; whilst the balms, or balsams, formed by a mixture of resin with ben-

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254. Whence is vegetable tallow procured?
255. What of camphor and its properties?
256. Describe resins, and gum-resins.

zoic acid, exist in a fluid state. The differences between these substances, however, are not very distinctly marked; for, though most of the gums are soluble in water, several cannot be dissolved unless by the aid of alcohol, and in their external appearances and properties they are almost identical. Again, they are so alike in their chemical compositions, that the most minute analysis has failed to detect any difference; hence chemists suppose that resins, gum-resins, and balsams are nothing but volatile oils, rendered concrete by the absorption of oxygen from the atmosphere. A portion of these substances is often exuded by the plant, either from a repletion of the receptacles, or from external injury; they essentially add to the durability of the timber, and preserve it from the attacks of animals; and, from their composition, would seem to be in some way connected with the functions of nutrition.

244. *The resins* are most abundantly yielded by the pine, or fir tribe, which contain the substance called *turpentine*, either in the vessels of the wood or bark. When turpentine is first obtained from the tree, it is in a liquid state; but after it has been allowed to settle, a solid substance is deposited, which, when purified by boiling, is the common yellow rosin, used in making soap, and for numerous other purposes. The liquid left after the deposition of the rosin is the turpentine of commerce, from which spirit of turpentine is procured by distillation, the residuum being the black rosin, or colophony, used by violin-players for their bows. *Tar* is procured by cutting the wood and roots of any of the pine tribe into small pieces, and charring them in such a manner as to allow the sap to run off during the process, which it does in the form of a thick black fluid. This fluid is the vegetable tar of commerce, from which pitch is obtained by boiling to dryness. Besides the turpentine drawn from the pine and fir tribe, there is some procured from a kind of pistachia, which is more delicate than the common kind, but much dearer, and more limited in its uses. Mastic and copal are resins derived respectively from a species of

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257. Their chemical nature.
258. What of turpentine and tar?

pistachia and rhus, and used in the preparation of varnish. Pitch, tar, and oil of turpentine, are all extensively used in the arts by ship-builders, joiners, painters, and many others.

245. *The principal gum-resins and balsams* are the following:—*storax*, which is derived partly from a species of styrax, and partly from the liquid amber; *benzoin*, which is produced by another species of styrax, and used in making paregoric; *balm of Gilead*, which is obtained from a species of amyris, now called balsamodendron; and *myrrh*, which exudes from several species of plants, such as the balsamodendron, laurus, and acacia. *Frankincense*, a gum-resin, highly valued for its perfume, is derived from a kind of juniper found in Arabia; and *balsam of Peru* and *balsam of Tolu* are procured from different species of myrospermum. *Gamboge*, extensively used in the arts and in medicine, is a gum-resin, obtained from several trees belonging to the orders Guttiflora and Hypericaceæ, natives of Ceylon, Siam, and Cochin-China. *Gum tragacanth*, now much used in calico-printing, is produced by a leguminous shrub, a native of the south of Europe; and *labdanum*, another gum-resin, by a species of cistus, found growing in Crete. Labdanum was formerly mixed with opium, in the belief that it neutralized some of the injurious effects of that drug; hence all the common preparations of opium are still called *laudanum*, though consisting of pure opium dissolved in spirits of wine. There are many other resins, gum-resins, and balsams, but those mentioned in this and the preceding paragraph are the principal. They are all obtained either from spontaneous exudations, or from artificial incisions made in the plants at certain seasons; the drier and warmer the climate and situation, the more powerful the properties of the secretions.

246. *The true gums* are distinguishable from the foregoing substances by their being entirely soluble in water, whilst alcohol does not act upon them. Their solution in water produces a thick adhesive fluid, of which dissolved gum-Arabic and gum-Senegal form familiar examples

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259. Describe the variety of balsams and gum-resins.
260. How are the true gums characterized?

These gums are obtained principally from artificial incisions in the bark of different species of acacia, though they also exude spontaneously, like the gum of the cherry tree in our own country. Gum exists more or less in every plant, and is one of their nutritive products—indeed the only one which can be absorbed and assimilated, without being first decomposed into water and carbonic acid, for plants have been known to thrive well upon a solution of it. It exists in the ascending as well as in the descending sap; it constitutes the *cambium*, or sap-wood, and in this form supplies material for the formation of cellular tissue.

247. *Caoutchouc*, or *Indian rubber*, a substance nearly resembling gum in its appearance, is derived from the latex of the ficus elastica, a kind of fig found in the East Indies, and in that of a Brazilian tree called *siphonia hevià*. It is found in many other plants, but not in sufficient quantities to be useful in the arts. When taken from the tree, caoutchouc is in a milky state, but by exposure to the air, it thickens into a kind of elastic gum, without colour, taste, or smell; the dark colour which it usually presents being derived from the fire over which it is dried. For many years it was only used for erasing pencil marks—hence its popular name of *Indian rubber;* but latterly, it has been extensively employed in the construction of elastic ligatures, and, from its being impervious to wet, in the formation of waterproof clothing. Being soluble in ether and naphtha it can be spread out into a thin coating, or varnish, over any substance; hence its adaptation to waterproof fabrics, air cushions, &c.

248. *Opium*, a product of a very different character from caoutchouc, is also derived from the milky juice which flows so abundantly in certain orders of plants during the flowering season. It is obtained in small amount from many plants, but chiefly from the poppy tribe; the white poppy (*Papaver somniferum*) being that which yields the opium of commerce. The juice is obtained by making incisions in the seed-vessels, or *heads*, when in a green

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261. Nature, sources, and uses of caoutchouc.
262. Describe opium, its source and properties.

state, and that which oozes out hardens by exposure to the air. In this state it forms crude, or lump opium, which, dissolved in spirit of wine and filtered, produces laudanum. Opium is a compound substance, consisting of a gum soluble in water, a small quantity of resin, and caoutchouc. Its powerful effect on the animal system is owing to two alkaline principles which it contains, namely, *morphia* and *narcotine;* the former producing a sedative, and the latter a stimulating effect. From this fact, it will be readily understood why opium should be smoked by the Chinese to produce intoxication, and swallowed by the invalid to procure him rest and insensibility to pain.

MISCELLANEOUS EXTRACTIVE PROPERTIES.

249. *Tannin*, which forms one of the best antiseptics, is a vegetable extract derived from the bark of many trees. It acts chemically upon all animal tissues containing gelatine; hence its economical importance to man. In the skin of animals, for instance, there is a great quantity of gelatine, which, when extracted, forms glue; and this substance, though it gives toughness and elasticity to the skin, is yet so liable to putrefy, that it would prevent the skin from being of any utility as an article of clothing, were its decay not prevented by the influence of tannin. For this purpose, the bark of oak, which contains a notable quantity of tannin, is steeped in water, and the skins are soaked in pits filled with the infusion, till they are converted into leather by the tannin penetrating their tissues, and thus rendering them capable of resisting decay. Tannin exists in the bark of most trees, some of which, like that of birch, communicates its fragrance to the leather; but in this country, it is only found in the oak and larch, in sufficient quantities to remunerate the preparation. Existing only in the bark, its physiological utility is apparent, in preserving the tissues of the vegetable from the decomposing influence of air and moisture.

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263. What is tannin, its value, and where found?

250. *Vegetable dyes*, which are of extensive utility in the arts, are obtained either from the roots, stems, leaves, or flowers of peculiar plants. Some are discernible in the native colour of the vegetable structure; others assume their economical colour only when extracted by a particular process. One of the most important is indigo, extracted from a leguminous plant grown in India, the leaves of which are steeped in water till the colouring matter of the cellular tissue has been separated from the framework of the leaf. The liquid is then drawn off, and evaporated, the colouring residuum, when dry, being the indigo of commerce. The importance of this dye may be estimated, when it is stated that the quantity grown in India is worth seven millions sterling a-year. It is used not only for dyeing blue, but as a preparation for dyeing black. Woad is another blue dye, obtained from the leaves of a plant known to the ancient Britons, and still cultivated in some parts of Lancashire. Logwood, which yields a purple dye, is the produce of the heartwood of a tree grown in the West Indies. The principal red dyes are madder, obtained from a plant grown abundantly in the south of Europe; archil, the produce of a lichen found in the Canary islands; alkanet, the root of an anchusa; and Brazil wood, the *duramen* of the cesalpína crista, a South American tree. The principal yellow vegetable dyes are obtained from a species of mignonette called the *dyer's weed*, and from the bark of the quercitron, one of the American oaks. Saffron, the stigma of a species of crocus, and turmeric, arnatto, and fustic, are also yellow vegetable dyes, as are the fruits of the rhaumus known in this country under the name of French or Avignon berries. Sap-green is also prepared from a species of rhaumus. Yellow and orange dyes can be obtained from the common heath; henna juice produces a permanent light brown; and all vegetables contain more or less colouring matter capable of affording brownish hues. In most cases, vegetable dyes are extremely evanescent, and are seldom used without the aid of what is called a *mordant*, to fix their colours;

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264. Whence are vegetable dyes procured?
265. Name some of the most important.

the mordants most commonly used being alum, copperas, and oxide of iron.

251. *The aromatic properties of plants* are chiefly contained in the bark, but they are also sometimes found in the seeds. The most remarkable are quinine, which is the inner bark of a tree nearly allied to the coffee; the bark of several kinds of magnolia; cinnamon, which is the inner rind of a tree nearly allied to the sweet bay; and sassafras chips, which are obtained from another tree belonging to the same genus. Aromatic qualities are also contained in the seeds of carraway, pepper, mustard, coffee, and numerous other plants.

252. *Mucilaginous matters* are produced by various kinds of mallow, and are employed in medicine as amulcents in coughs, hoarseness, &c. Other vegetable products are used for the same purpose, such as the juice of the liquorice plant.

253. *The astringent and drastic properties*, which render vegetable preparations so valuable in the pharmacopœia of the apothecary, are possessed by many plants. The leaves of the tea-plant, the galls of the oak, the leaves of the brambleberry, and the husks of the walnut, are astringents. The aloe, colocynth (which is the pulp of a small gourd called the bitter apple), and jalap, which is obtained from a kind of convolvulus found at Xalapa, in Mexico, are possessed of purgative or drastic properties. Gamboge, and other vegetable products, are used as drastic medicines, the former being poisonous when taken in excess.

254. *Acid properties* are found in many vegetables, and are frequently so intense as to be poisonous—as, for example, oxalic acid, which is obtained from the wood-sorrel, and prussic acid, which is extracted from bitter almonds, the kernels of peaches, and other allied fruits, and from the leaves of the cherry, laurel, &c. The most abundant and useful acids are the citric, which is found in the orange and

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266. What are mordants, and examples ?
267. What of aromatics ?
268. Define mucilage, its source and properties.
269. Examples of astringents and drastics.
270. Sources and variety of vegetable acids.

lemon tribe, and is used in food as well as in the manufacture of morocco; the mallic, obtained from apples and pears, and is that which gives the acidulous flavour to cider and perry; and the gallic, derived from the galls of the oak, and used both as an astringent, in dyeing black, and in making ink. Besides these, there are tartaric acid, found free in certain fruits, but principally obtained from the crust deposited on the inside of wine casks, in which it exists in combination with potash, forming *cream of tartar;* and pyroligneous acid, obtained from the wood of the fir-tribe by distillation. Both of these acids are used by the dyer and calico printer; and the latter, which resembles strong vinegar with a tarry flavour, is also extensively used as an antiseptic. Creosote, well known in medicine, is obtained from pyroligneous acid, by separating the tarry matter.

255. *Of the alkaline properties* of vegetables may be mentioned morphine and narcotine (already noticed), and quinine, which is extracted from cinchona. The salts of potash and soda are abundantly found in many plants, especially those growing near the sea; and from these, till lately, the soda of commerce was wholly obtained. It is now derived from sea salt (muriate of soda) by a chemical process.

256. *Vegetable poisons* are principally of two kinds—the acrid and stupifying. The poison of some of the ranunculuses is the former class; that of the poppy belongs to the latter. Of the secretions and excretions already mentioned, many are poisonous when taken in excess; even the fumes of some are productive of deleterious effects.

257. *The substances above enumerated* are partly secretions and partly excretions; those being regarded as excrementitious which are naturally exuded by the living vegetable. Of this kind are wax, several resins and gums, the caustic juice of the stinging nettle, and the clammy substances found on the leaf-buds of the chestnut, the calyx of the moss rose, &c. The most remarkable of the excretions

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271. Alkaline products of vegetables.
272. Vegetable poisons, varieties and examples.
273. Distinctions between secretions and excretions.

are those juices discharged by the roots, which appear either as acid, milky, mucilaginous, or saccharine products.

258. *Besides the proper secretions and excretions*, there are other products alike subservient to the purposes of the plant and to human economy. Of these the principal are the woody fibre of the flax, from which linen is made; the down which surrounds the seeds of the gossypium, from which cotton is obtained; the woody fibre of the hemp and the cocoa nut; and the bark of the cork tree.

259. *Lastly, there are many adventitious substances* found in plants, which are not the products of vital organization. Lime, for instance, is found in the ashes of many plants in union with acids, and sometimes it is excreted in the form of a thin crust on their leaves. Silica also occurs in considerable quantities, especially in the stems of reeds and grasses; it forms the glossy pellicle of the cane, and is sometimes found in the joints of the bamboo, where it is deposited in a soft pasty mass, which ultimately hardens into pure semi-transparent silica. Besides these earths, there are various metallic oxides and salts, and the well-known alkalies, potash and soda.

260. *The physiological uses of the products above enumerated* are but imperfectly known. Many of them—such as starch, gum, sugar, and the fixed oils—directly administer to the support of the young plant and to the formation of new tissues; while those which yield flavour and aroma seem to be connected with the preservation of plants, by protecting them from the depredations of insects and other animals. Others, again, such as silica and metallic oxides, give hardness and stability to the stems and branches; some give elasticity and pliancy to the young shoots, thereby preventing them from being broken by winds; and several administer to the durability of the woody fibre, by their properties of resisting putrefaction. It is nevertheless true, that the purposes which many of the so-called secretions and excretions serve in the economy of vegetation are by

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274. What other products of value ?
275. What earths, metals and salts are found in plants ?
276. Physiological uses of all.

no means evident. Physiologists are as yet but partially informed, satisfying themselves with the general statement, that all these products are either necessary to the growth, propagation, or preservation of the plant, or are excreted to maintain it in a healthy condition.

METAMORPHOSES OF PLANTS.

261. *The Metamorphoses of Plants* forms one of the most interesting sections of Vegetable Physiology. Technically, it is termed *Morphology*—that is, a consideration of the changes and transformations which various parts of plants undergo, either from natural or artificial causes. We know, for instance, that many plants are made to change their appearance and qualities by cultivation ; that by grafting, hybridizing, and so on, the gardener can change the size, colour, and qualities of his fruits and flowers ; and that analogous changes take place in a state of nature, such as the conversion of leaves into petals, and leaves and branches into thorns and spines. It is also well known that flowers become double by changing their stamens into petals ; and it is from a knowledge of these facts that botanists have asserted that all the appendages of the stem or ascending axis are modifications of a single organ, and may be considered *as leaves adapted to a special purpose.* This doctrine, at first broached by Linnæus, and subsequently expounded by the celebrated Goëthe, is now very generally adopted. It is usual to treat of this subject under two heads, namely, *regular* metamorphosis, or that connected with the structure of all vegetables ; and *irregular* metamorphosis, or that which influences only a particular class of plants, or parts of those plants, and which occur under peculiar circumstances.

REGULAR METAMORPHOSIS.

262. *Regular metamorphosis* embraces those transformations which are applicable to all vegetables. It presumes

277. Define morphology, and varieties named.
278. How classified ?
279. Define regular metamorphosis.

that, if the organ can be transformed into another, there is an identity in their origin and nature. If, for example, leaves are sometimes converted into bracts, bracts into a calyx, and the calyx into a corolla, then it is almost self-evident that the corolla, calyx, and bracts, have the same origin as the leaves. Regular metamorphorsis seeks for facts to establish this doctrine, namely, that all the appendages of a plant have a common origin with the leaf, and may therefore successively assume the form and appearance of that primary organ.

263. *All the appendages of the stem are modifications of leaves*, transformed to subserve some special purpose. The first protrusion of the plumule from the embryo is leaf-like, subsequently true leaves are developed, and from a succession of these are formed the stem. The branches of the stem take their origin from leaf-buds, and are again clothed with branches and leaves by the same process as in the main stem. As a branch proceeds towards the point of fructification, the leaves assume the form of bracts, these again are succeeded by the leaf-like sepals of the calyx, and next by the petals of the corolla. Within the petals are the stamens, which sometimes assume a leafy form, next the pistil, and ultimately the seed-vessels. Even the seeds are but leaves in another form, embalmed and preserved, as it were, for the reproduction of another plant; and in many, such as the beech-mast, the leaflets of the embryo may be distinctly seen, folded and imbedded in their future nutriment. Thus, the growth and reproduction of plants may be regarded as a circle of leaf-like changes, the leaf, or some modification of it, being in all cases the organ which administers to the functions of vitality.

264. *In stipules and bracts, the leafy origin* is abundantly evident. The former are more or less developed in all plants, and may be considered as rudimentary leaves, or parts of the leaf. Bracts, again, are always intermediate between true leaves and the calyx, forming the boundary between the period of growth and that of fructification. In

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280. What are modifications of leaves?
281. What of stipules and bracts, sepals and petals?

some roses, for example, the bracts are exactly similar to the leaves, while in the tulip, they frequently partake both of the colour and texture of the sepals. Bracts, like true leaves, have buds in their axillæ, as may be seen in the rose and common daisy. Bracts also mark the transition from growth to inflorescence, by their mode of arrangement. Leaves may be alternate or whorled on the stem, while the floral appendages are always whorled or verticillate: the bracts generally represent the transition to this whorled arrangement.

265. *That there is no essential difference between the sepals of the calyx and the petals of the corolla* is evident from the sepals being frequently coloured, and forming the most beautiful portion of the blossom. In the monkshood, the blue part which forms the flower is botanically the calyx, the petals being entirely concealed under the hood. In the fuschia, the bright scarlet part is the calyx, and the small purple petals within, the corolla; while in the tulip and crocus, the sepals and petals are all coloured alike, so that it would be impossible to distinguish one from the other, did not the sepals grow a little lower on the stem. In many plants, the petals and sepals are identical in colour, texture, and odour ; and when the perianth is single, they seem to be combined.

266. *In like manner there is no physiological difference between the petals and leaves.* Both have a framework of veins, the interstices of which are filled up with cellular tissue, and both have an epidermis furnished with stomata. The absolute change of leaves into sepals, and thence into petals, may be occasionally seen in the tulip, the bracts or floral leaves of which are sometimes partially coloured, like the proper petals of the flower.

267. *The construction and arrangement of the stamens point to the same leafy origin* as the corolla and calyx. The stamens which form the third whorl, or series of fructification, have occasionally their filaments dilated and leaf-like, as in the white water-lily and barberry. In many cases—

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282. How is the leaf shown to be the fundamental structure ?

such as the double roses, anemones, ranunculuses—a transition is observable from the outer petals of the corolla to the true stamens; the petals gradually becoming smaller, and ultimately assuming the colour and form of stamens.

268. *The sepals, petals, and stamens, always correspond in number.* For example, if there be five petals, there will be five sepals, either separate, or slightly adhering together, and generally the same number of stamens. Sometimes, however, the stamens are more numerous; but they always consist of some multiple of the original number of petals—as, for instance, when there are five petals, there will be five, ten, or twenty stamens. Five, three, or six, are the most common number for petals; four is very rare; and seven has never yet been met with.

269. *The fourth series, or concentric whorl of fructification, is the discus,* which is so frequently absent, and of so obscure a nature when present, that few morphologists take it into their consideration. Dr. Lindley seems inclined to regard it as a modification of the stamens, and consequently partaking of the nature of that fundamental organ, the leaf. "M. Duval," says he, "has noticed half the disk of a cistus bearing stamens; and a variety of instances may be adduced, of an insensible gradation from the stamens to the most rudimentary state of this organ."

270. *The pistil and ovary,* which form the last of this concentric series, seem formed in the same way by the metamorphosis and union of leaves. Many pistils have a laminated, or blade-like shape, and the stigma of some, such as the iris, is leafy (see fig. 66). The leafy origin of the ovary is still more perceptible—a follicle, for example, being evidently composed of one or two leaves folded, and adhering at the edges. The same may be said of other carpels; and even a pome (fig. 70) may be regarded as several leaves metamorphosed by an increase of cellular tissue, and united so as to form one continuous mass. The leafy origin of fleshy fruits is often very perceptible when newly formed, or when by some accident they are rendered abortive at this stage.

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283. Name the various illustrations.

271. *What are called monstrosities in flowers*, furnish another evidence that the floral appendages are merely modifications of the leaf, or at least that the same structure is common to both. These monstrosities generally arise from some accidental circumstance operating, so as to change the flower-bud into a leaf-bud during the germination of the flower. Thus, if a plant be supplied with abundance of moisture and warmth, but with little sunlight, the growing point will be developed into a bud in the centre of the flower, and sometimes a second flower will be produced at the extremity. We also know, that removing a wild plant into a garden has a tendency to make the flowers double; because the richer soil affords so much nourishment, that enough of cellular tissue is produced to change the stamens into petals.

272. *Leaves and branches are frequently transformed into spines and thorns.* Indeed, thorns are regarded as leaf-buds which have been rendered abortive by some accidental stoppage of the sap, which prevents the addition of cellular tissue sufficient to form perfect leaves. Branches, which also take their origin from leaf-buds, may be arrested at a certain stage of their growth, so as to form spines instead of perfect branches; and such spines not unfrequently give birth to new leaf-buds and leaves, as may be seen in the common hedge-thorn.

273. *In conclusion*—"We see," says Dr. Lindley, "that there is not only a continuous uninterrupted passage from the leaves to the bracteæ, from bracteæ to calyx, from calyx to corolla, from corolla to stamens, and from stamens to pistillum—from which circumstance alone, the origin of all these organs might have been referred to the leaves—but there is also a continual tendency on the part of every one of them to revert to the form of the leaf."

IRREGULAR METAMORPHOSIS.

274. *Of irregular metamorphosis*, or those changes which parts of plants, or classes of plants, may be made to assume,

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284. What of monstrosities in flowers ?
285. Other transformations.
286. Define irregular metamorphosis.

little is absolutely known. In a state of nature, certain tribes are limited to certain localities, these situations being characterized by some peculiarity of soil and atmospheric influence. If the conditions of soil and climate to which they are subjected remain the same, the character of plants is nearly uniform or stationary; and this may be always said of them in their natural state. But if they be removed from a poor to a rich soil, from a dry to a moist habitat, from a warm to a cold climate, or *vice versa*, then their internal structure will undergo a change; and this change will manifest itself in one or other of their external characters. In some classes, this change is most evident in the roots and tubers; in others, in the stems and leaves; while in many, the organs of fructification (the flowers and fruit) are the parts most affected. Sometimes this change of situation merely produces a more luxuriant development of all the parts of a plant, without causing any abnormal growth of a particular organ. Cultivation, and other artificial treatment may be considered as the cause of these irregular metamorphoses, which assume in some plants a wonderful degree of permanency, and may be transmitted to successive races; though, generally speaking, if the artificial stimulus be not kept up, plants will return to their normal or natural condition.

275. *The changes which roots and tubers* can be made to undergo are numerous, and highly beneficial to man. The potato, for example, is a native of tropical America; and when found wild there, its tubers are small, and scarcely, if at all, edible; while in Europe, it has been rendered by cultivation one of the most valuable articles of food. The produce of an acre of wild potato could be carried in a single measure, while in Britain, the same extent will yield from forty to sixty bolls. Cultivation has also produced a thousand varieties of this tuber, varying in shape, size, colour, and quality: even in one year, a change of soil will sometimes cause a difference, not only in quality,

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287. What of transplantation?
288. Name examples of the changes in roots and tubers.
289. Varieties in climate and effects.

but in colour and appearance. Beet, parsnip, and turnip, are also made to assume many varieties under judicious cultivation. The bulb of the latter, for instance, has, since the beginning of the present century, been metamorphosed into forms from globular to fusiform, in colours from white and yellow to purple and green, and in weight from a couple of ounces to twenty pounds. So, also, with the carrot, which in a wild state is a slender tapering fleshy root, of a yellowish-white colour, but which by cultivation increases in size, and assumes a deep red or orange colour. In the one case, the root is not much thicker than a common quill, in the latter, it becomes as thick and long as a man's arm. Nor are we aware of any limit to such metamorphoses; more numerous and more gigantic varieties may yet be reared by superior cultivation.

276. *The stem is less subject to irregular metamorphoses* than either the roots or tubers. It has been already stated (par. 31), that if a tree which is a native of mountains be placed in a valley, it grows more rapidly, and its timber becomes softer and of less value; and, in like manner, if the tree of a valley be removed to a mountain, it becomes of slow growth, and small dimensions, but produces timber remarkable for its toughness and durability. Generally speaking, stems in hilly regions became short and hardy, in low and moist situations long and of softer texture, in open plains firm and coloured, and in shady recesses slender and delicate. By cultivation, tall stems are for the most part rendered short, and short ones taller—the dahlia, for example, having been reduced to one-half of its natural height by garden culture. The cabbage, in its wild state, has a tough slender stem, which by culture has become fleshy and fusiform; and so also of many other culinary plants. Sometimes the stems of cultivated plants assume a double or triple appearance, as if two, three, or more individuals had been glued together. Stems in this state are said to be *fasciated*, or bundled, but are in reality single stems, and not a mere accidental adhesion of several individuals.

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290. What of the stem? Illustrations.

277. *Leaves are subject to innumerable metamorphoses,* arising either from culture, change of season, disease, or injury by insects. From a thin and tough condition, they will sometimes become succulent, and roll inwards, forming what is called a *heart,* as in the common cabbage and lettuce. In others, the paranchyma and margin are produced in excess at certain stages of growth, so as to convert plain leaves into a puckered and irregular shape, as in the curled cress, curled savory, &c. Trees and shrubs with notched, lobed, and compound leaves (par. 103), will, by being transplanted to a rich soil and warm situation, become simple and entire; even pectinate leaves, under similar treatment, will become fleshy, and fan-shaped ones lobed. Sudden changes of weather, such as from excessively dry to wet, or the reverse, occasionally produces strange metamorphoses among leaves; so likewise do the injuries received from the stings and larvæ of insects.

278. *The metamorphoses which occur in the floral organs* are also very frequent; and on this feature depends all that variety and beauty which it is now so much the object of the florist to produce. These transformations consist in an increase of the petals, in a conversion of petals into stamens, and in some modification of the colour. What are called *double* flowers, and produced by a multiplication of the petals, as in the common varieties of the rose; and *full* flowers are those in which the multiplication is carried so far, as to obliterate the stamens and pistil. In a wild state, for example, the rose produces but a single row or verticil of petals, surrounding a vast number of stamens; but when cultivated, several rows of petals are formed at the expense of the stamens, which are proportionally diminished. "With regard to colour," says Dr. Lindley, "its infinite changes and metamorphoses in almost every cultivated flower can be compared to nothing but the alterations caused in the plumage of birds, or the hairs of animals by domestication. No cause has ever been assigned to these phenomena, nor has any attempt been made to determine the cause in plants.

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291. Agencies operative upon leaves.
292. Varieties in flowers.

We are, however, in possession of the knowledge of some of the laws under which change of colour is effected. A blue flower will change to white or red, but not to bright yellow; a bright yellow flower will become white or red, but never blue. Thus the hyacinth, of which the primitive colour is blue, produces abundance of white and red varieties, but nothing that can be compared to bright yellow, the yellow hyacinths, as they are called, being a sort of pale yellow ochre verging to green. Again, the ranunculus, which is originally of an intense yellow, sports into scarlet, red, purple, and almost any colour but blue. White flowers, which have a tendency to produce red, will never sport to blue, although they will to yellow; the roses, for example, and the crysanthemums." For further remarks on the subject of colour in flowers, see par. 212–217.

279. *The changes which the fruit or seed undergoes* are also very numerous and obvious. Where, for instance, is there a native grain like wheat, or a native fruit like the apple? In a wild state, the seeds of our cereal grains (wheat, barley, oats, &c.) are thin and meagre; by proper cultivation, they are rendered large, plump, and full of farina, so as to become the most important articles of human sustenance. Numerous varieties of these grains, each differing in colour, flavour, durability, &c., are now raised by cultivation; so that, compared with their originals, their value is more than a thousandfold. The small globular sour crab apple of our hedges is the original of the numberless varieties of apple now cultivated by gardeners, each variety differing somewhat in size, shape, colour, and flavour. So also with the sloe, which is the parent of our purple, yellow, and white plums; with the wild cherry, and almost every species of cultivated fruits and seeds. Besides the changes which are steadily effected by cultivation, there are frequent sports in the fruit, as in the blossom or flower. In the orange, a second fruit is sometimes produced inside the outer, agreeing in all respects with the outer fruit; and in

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293. Examples of floral transformation.
294. Changes of fruit and seed, examples.
295. Whether spontaneous or by cultivation.

the apple and cherry, double and triple fruits, analogous to fasciated stems, are frequently to be met with.

HYBRIDISM.

280. *The hybridism of plants* is closely allied to the subject of morphology, and is in fact a transformation of character produced by artificial means. As among animals two distinct species of the same genus will produce an intermediate offspring—such as the *mule*, which is the offspring of the horse and ass—so among vegetables two species belonging to the same genus can be made to produce a *hybrid;* that is, a new plant possessed of characters intermediate between its parents. This power of hybridizing is more prevalent among vegetables than animals; for the different species of almost every genus of plants are capable of producing this effect, if the pollen of one species be put upon the stigma of another. This union, however, can only take place between nearly allied species; it occurs rarely among plants in a wild state, but is quite common among cultivated species. According to modern botanists, the character of the female parent predominates in the flowers and organs of fructification of the hybrid, while its foliage and general constitution are those of the male parent.

281. *Hybrids have not the power of perpetuating their kind* like naturally distinct species. Mule animals, for instance, are uniformly incapable of procreation, unless with one of their parent species; so also with vegetable hybrids, which, though occasionally fertile in the second and third generations, have never been known to continue so beyond the fourth. If impregnated with the pollen of one of its parent species, a hybrid plant will give rise to a new hybrid, partaking more of the character of the original parent; and if this process be continued for two or three generations, the hybrid will ultimately return to the pure

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296. What of the hybridism of plants?
297. Analogy from the animal kingdom.
298. Peculiarities of hybrids.

species. Thus, though hybrids are incapable of propagating themselves beyond a very limited period, the pollen of the parent species may be made to fertilize them, or their pollen to fertilize the parent; but in either case the new offspring gradually merges into the original species. Thus nature has wisely set a limit to the intermingling of species, by which they are preserved from ultimately running into confusion and disorder. The cause of sterility in hybrids is unknown; for, in general, there is no perceptible difference between the perfection and healthiness of their organs and those of the parent species.

282. *In an economical point of view*, hybridism is of great value to man. By a knowledge of its principles, he has been enabled to modify the characters of natural species, so as to adapt them to his special purposes, and thus have arisen most of those beautiful sorts and varieties of blossom which now adorn the flower-garden. So, also, by crossing varieties of the same species, our grains, fruits, and kitchen vegetables have been brought to a high state of perfection. The size of one species has been assiduously amalgamated with the durability of another, the beauty of a third with the flavour or odour of a fourth, and so on with other qualities, till we have now as many perfect vegetables as it seems possible to produce. The principles of hybridism will yet be more extensively applied; and it is not too much to expect that the perfection of our field and forest produce will yet rival that of our orchards and gardens.

GEOGRAPHICAL DISTRIBUTION OF PLANTS.

283. *The geographical distribution of plants* is influenced by conditions of soil, heat, moisture, light, altitude of situation, and various other causes; for, did they flourish independently of these conditions, then there were no reason why the vegetation of one part of the globe should differ from that of another. We know, however, that the flow-

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299. Value to horticulturalists.
300. Examples of hybridism.
301. What of the geographical distribution of plants?

ers, shrubs, and trees which adorn the plains of India are not the same with those which clothe the valleys of Britain; and that these, again, are totally different from the scanty vegetation of Iceland or Spitzbergen. Each order is, nevertheless, perfectly adapted to the conditions under which it exists, and finds in its *habitat*, or native situation, all the elements which administer to its growth and perfection. A knowledge of these conditions, and of the various vegetable tribes which flourish under them, constitutes the subject of botanical geography.

284. *The influence of soil, climate, &c. upon vegetable life* is very obvious; but the manner in which it operates is but imperfectly known. The same elements enter into the composition of the vegetation of the tropics as those which form the vegetation of temperate regions; the same organs, tissues, modes of growth, and inflorescence, are observable; and yet, without the external conditions above enumerated, a plant which has been transferred from the one region to the other will speedily languish and die. Even one which flourishes under the influence of the sea-breeze, if removed far inland, will perish; and no art can retain in healthy perfection a native of the mountain which has been transplanted to the warm and humid valley.

285. *Certain plants, like animals, may, however, be acclimatized;* that is, may be made to grow and propagate their kind in a region in which they do not naturally occur. Many of our cultivated and most useful plants are of this kind; as, for example, the potato. This plant, which is a native of tropical America, flourishes luxuriously, and is of the highest utility, in northern Europe; but this it does by a special adaptation. In South America, the warm climate enables it to propagate by the seed; hence in that region its tubers are small and insignificant; but in Europe, where the climate is unfavourable to the production of the plant from seed, it propagates by the tubers, which are consequently enlarged, so as to contain a store of nutriment for

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302. Influence of climate upon vegetable life.
303. What of acclimation?
304. Illustrations of acclimation.

the young plant before the stem and leaves be sufficiently developed. The acclimatizing of plants does not permanently change their character, for, in being restored to their native habitats, they assume their original forms and qualities.

286. *The habitats of plants*—that is, the situations in which they naturally thrive best—depend upon the conditions of soil, climate, &c., already alluded to, and are generally distinguished as follows:—*Marine* when the plants float upon or are immersed in salt-water, such as sea-weeds; and *maritime* when they grow by the sea-shore, or in places exposed to the influence of the sea-breeze. *Aquatic* is the general term for fresh water habitats; and these may be either *lacustrine* when growing in lakes, *fluviatile* when in rivers, or *palustrine* when in marshes or wet meadow-lands. Plants growing in open pastures are said to be *pratensine*, in cultivated lands *arvensine*, in woods *sylvan*, in mountainous parts *alpine*, and in caves, mines, and other underground excavations, *subterranean*. The station of a plant is said to be *epiphyte* when it grows upon others, living or dead, without deriving from them the elements of nutrition; and *parasitic* when it adheres to their surface, and directly extracts its nourishment.

287. *The range of habitat* is that extent of the earth's surface over which a plant is distributed by nature. The terms maritime and alpine, for example, are general in their application, and refer to all plants which grow by the sea-side or on mountains; but the plants which flourish on the sea-shores of Great Britain are not the same with those on the coast of Africa; nor are these, again, allied to the maritime vegetation of Chili. The geographical range of any plant conveys a more specific idea, and embraces only that particular spot in which the plant rejoices. This range is circumscribed by conditions of temperature, light, and elevation above the sea, and does not, as might be supposed, depend very closely upon belts of longitude, by which temperature is generally indicated. Thus, nearly all the beauti-

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305. Classification of plants according to their habitats.
306. The range or limit of habitat.

ful pelargoniums and mesembryanthemums which adorn our greenhouses are natives of a limited space near the Cape of Good Hope, as are also many of our most beautiful bulbs. The curious stapelias, that smell so much like carrion, are found wild only in South Africa. The different kinds of eucalyptus and epæris are only found in Australia; and the trees bearing balsam grow principally in Arabia and on the banks of the Red Sea. The umbelliferous and cruciferous plants spread across Europe and Asia; the cacti are found in tropical America; and the labiatæ and cariophyllaceæ are seldom discovered but in Europe. The peculiar ranges and centres of vegetation, as they are termed, cannot be well understood without a knowledge of the different tribes and classes of plants, the consideration of which forms the subject of SYSTEMATIC BOTANY.

288. *The soil exercises less influence on the distribution of plants* than is usually ascribed to it, though there can be no doubt that on its power of absorbing and retaining heat and moisture much of the luxurious growth of vegetables depends. They will grow to some degree in almost any soil, as the bulkier ingredients (clay, lime, and sand) always predominate (par. 23); but a proper proportion of these earths is necessary to perfect vegetation; and many plants will not continue healthy and propagate, unless supplied with other elements, such as potash, soda, and various metallic salts. For this reason the natural vegetation of a limestone country differs from that of a retentive clay; while the plants which cover all sandy downs are totally different in kind and character from those of the alluvial valley. For this reason, also, it is that some soils become exhausted of the elements necessary to the perfect growth of a certain race of plants, and that these plants are succeeded by a new tribe, which still find in the soil all the constituents of their growth and perfection (par. 25, 26).

289. *Moisture,* which is indispensable to the existence of vegetation, also exercises some influence in its natural

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307. Illustrations named.
308. Effects of soil, and its changes.
309. What of moisture?

distribution. The plant which roots in the parched sand is furnished with leaf-organs to absorb moisture from the atmosphere, and retain it, while in a wet situation these organs would become diseased, and rot away; so, in like manner, a marsh plant, whose spongioles are its main organs of sustenance, would perish were it removed to an arid soil. The organic structure of such plants forms a limit to their distribution; and the same may be said of the salicorniæ, arenaria peploides, &c., which live only when exposed to the salt spray of the ocean.

290. *Heat and light* are perhaps the most manifest agents in the distribution of vegetable life. The luxurious growth of the tropical jungle is the direct result of warmth and moisture, just as the barrenness of Nova Zembla is the effect of piercing cold; yet both situations are inhabited by plants which enjoy the conditions peculiar to their existence. No conditions of mere soil, or light, or moisture, could make the palms, tree-ferns, and jungle-flowers of India flourish in Great Britain; so neither would our oaks or pines flourish in Iceland, unless we could provide for them that temperature and seasonal influence necessary to their existence. Light, though it acts most powerfully on the colours and blossoms of plants, is also an essential element in their geographical arrangement. The southern slopes of our hills and mountain ranges are always clothed with a more elaborated and more fully developed race of plants than the northern slopes, and this depends wholly upon the greater degree of light which the former enjoy. The northern side may sometimes be as green, but it will never be so flowery as the southern exposure; and the attentive observer may detect new tribes on either side almost as soon as he has passed the summit.

291. *Altitude, or elevation above the ordinary sea-level,* also exerts an obvious influence on the distribution of vegetable life; it is equivalent to removal from a tropical to a temperate region, or from temperate latitudes to the arctic circle. For every hundred feet of ascent, there is a pro-

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310. What of heat and light? their effects.
311. Examples of altitude, and its influence.

portional fall of the thermometer; so that at the height of 5000 feet in Britain, and 16,000 at the equator, we arrive at the region of perpetual snow; in other words, to heights as destitute of vegetation as the frozen zone. This intimate relation between altitude and decrease of temperature accounts for the fact, why the base of a mountain may be clothed with the vegetation of tropical India, the sides with that of temperate England, and the summit with the mosses and lichens of icy Labrador. Many mountains exhibit such belts of vegetation; the most familiar instances being Mount Ætna, Teneriffe, and the Andes.

292. *The circumstances which facilitate the dispersion or migration of plants* are unconnected with the causes which limit their geographical distribution. Many seeds drop from the parent stalk, spring up into new series of stems, which in turn give birth to another race of seeds, and these, again, to another circle of vegetation. Thus, any tribe of plants would spread from a common centre till arrested by the influences which limit its range of habitation; and this mode of dispersion no doubt occasionally occurs. In most plants, however, the seeds are small and light, and easily borne about by the winds; some are downy, and furnished with wings; others have tufts and filaments; and many are ejected from their carpels with considerable force. All these appendages and peculiarities are evidently intended to facilitate their dispersion, which is further assisted by rivers, lakes, and tidal currents, by the wool of animals, the droppings of birds, and the economical pursuits of man, whether accidental or intentional. The seeds are arrested in their progression by various causes; some are furnished with barbs and hooks, which lay hold of objects, others become entangled amid herbage, the mud of rivers, or the softened soil of winter, while many towards spring are acted upon so as to emit an adhesive substance, or their fleshy pericarps melt down into the soil, carrying the embryo along with them. In all, the appendages which aid their migration begin to decay at the proper season, and so are unfitted any longer to transport them.

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312. Wonderful dispersion and migration of plants.

293. *Botanical geography* is thus both an interesting and intricate subject. To enter fully upon the influences of temperature, altitude, &c. would require a pretty extensive knowledge of physical geography; and even then, without an acquaintance with the various classes of plants, the special effect of these influences could be but imperfectly understood. A general idea of the subject, however, has been given in the present section, from which the student will perceive that every plant is perfectly adapted to the situation it is created to fill; and that there is no portion of the globe—the regions of perpetual snow and the moving sands of the desert scarcely excepted—which does not administer to the growth of some plant, which has not some form of vegetation to adorn its surface.

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313. Define botanical geography.

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☞ *The Figures in the columns beneath refer to the paragraphs in the text in which the particular term or subject is fully explained.*

THE END.