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ELEMENTS
OF
VEGETABLE AND ANIMAL
PHYSIOLOGY.

In Two Parts.

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.

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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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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?

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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 functions 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.

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?

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

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

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

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

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

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 the 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,*

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

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,

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.

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*, *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.

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?

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,

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

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*,

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.

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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

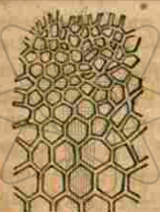

Fig. 1.—Cellular Tissue in a Leaf.

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-

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

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,

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

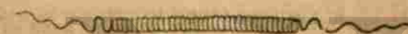

Fig. 5.—Spiral Vessel.

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

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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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

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. 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

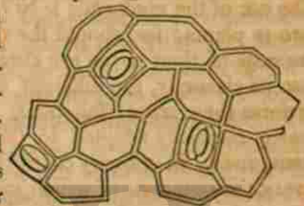

Fig. 6.—Stomata of a Leaf.

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 drying 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.

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

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

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

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

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 fecu-lent 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

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.

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

81. What of under-ground stems, bulbs, etc.?
82. Nature and functions of the woody part of roots.
3. 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;

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

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

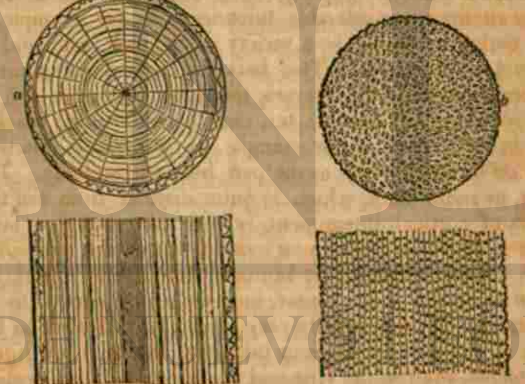

Fig. 17.—Sections of Exogenous and Endogenous Stems.

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 vasculaı 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

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,

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

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

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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

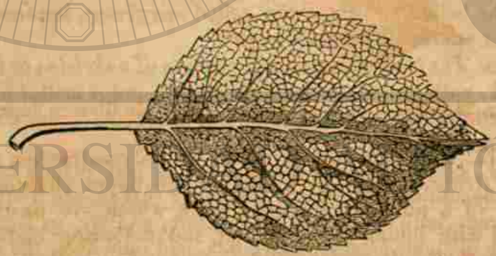

Fig. 28.—Reticulated Venation of a Leaf of an Apple-tree.

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).

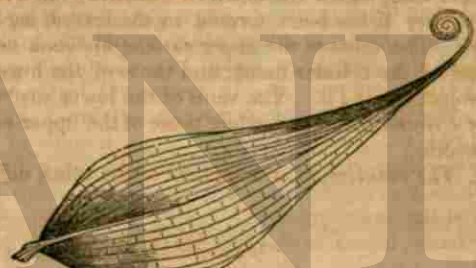

Fig. 29.—Muriform Venation of a Leaf of the Gloriosa Superba.

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

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-

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 ma jor convolvulus; *reniform*, or kidney-shaped (*b*), as in the ground ivy; or *tongue-shaped* (*c*), as in some kinds of me

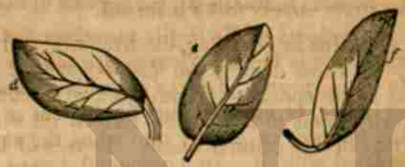

Fig. 31.—Oval (*d*), Ovate (*e*), and Elliptic (*f*) Leaves.

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

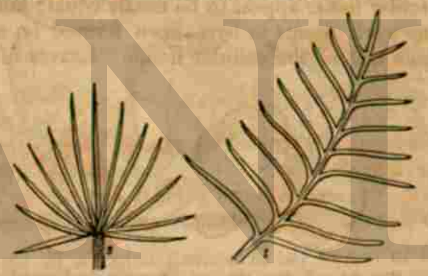

Fig. 37.—Fan-shaped (*s*) and Pectinate (*t*) Leaves.

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),

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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

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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-

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

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,

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

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

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

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

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.

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,

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

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

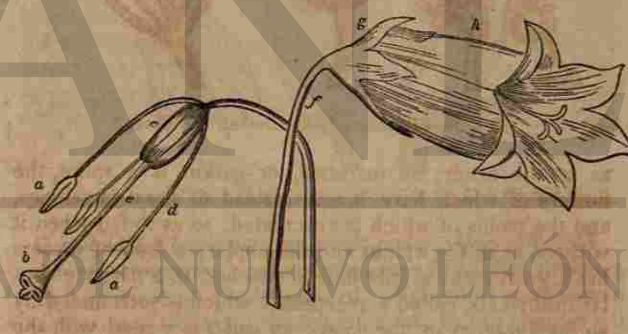

Fig. 59.—*a a*, Stamens; *b*, Stigma, or Summit; *c*, Ovary, or Seed-Bag; *d*, Filament; *e*, the Style; *f*, Peduncle; *g*, Calyx; *h*, Corolla.

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

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.

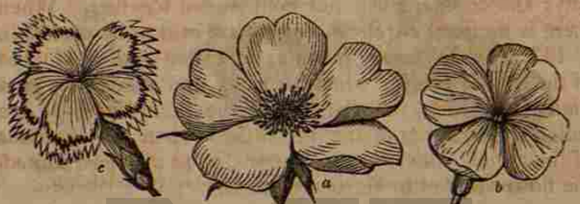

Fig. 61.—Caryophyllaceous (*c*), Rosaceous (*a*), Cruciform (*b*).

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

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

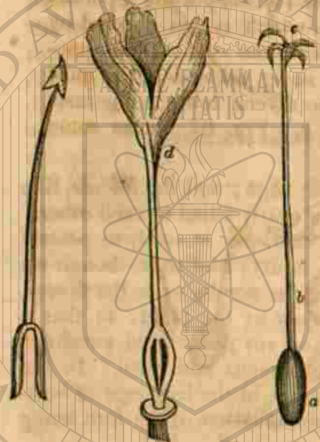

Fig. 66.—Pistils.

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

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-

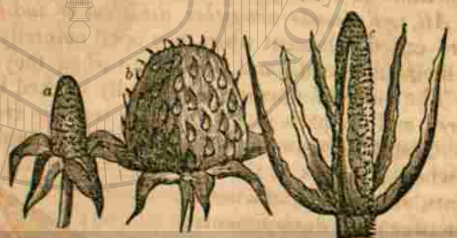

Fig. 68.—Receptacles of Raspberry (*a*); Strawberry (*b*); Teazel (*c*).

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.

Fig. 69.—Follicles.

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

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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,

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;

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

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.

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 apple 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

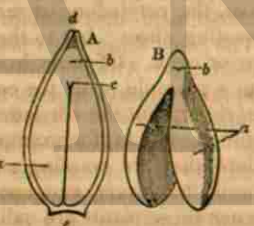

Fig. 73.—Seed entirely filled with the Embryo.

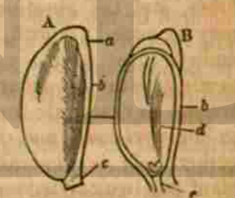

Fig. 74.—Seed with a large Albumen and small Embryo.

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

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 indiscriminately 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.

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

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

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

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-

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

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-

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

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-

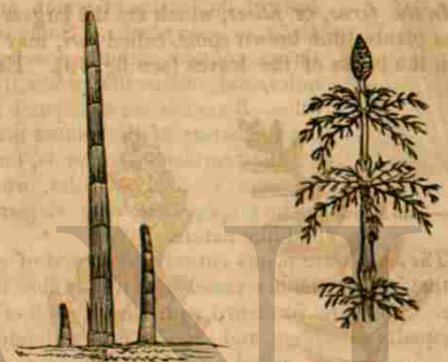

Fig. 80.—Equisetaceæ, Simple and Branched.

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

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

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

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

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

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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

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 *Hedysarum 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.

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

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

in minute granules in the vesicles of the cellular tissu 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

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-

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*

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.

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

6

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.

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.

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-

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.

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

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

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

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

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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

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

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

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-

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

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

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

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.

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 cesalpina 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;

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

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

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

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

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

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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—

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.

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

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,

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.

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.

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

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

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 flowers, 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

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

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

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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 flowers, 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.

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

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

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-

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

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-

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.

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.

INDEX.

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

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THE END.

ELEMENTS

OF

PHYSIOLOGY

PART II.

ANIMAL PHYSIOLOGY.

CHAMBERS' EDUCATIONAL COURSE.

THE END.

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OF

PHYSIOLOGY

PART II.

ANIMAL PHYSIOLOGY.

CHAMBERS' EDUCATIONAL COURSE.

INTRODUCTION

BY

THE AMERICAN EDITOR.

The value of knowledge in relation to human physiology, and the acquaintance with the laws of health and life which such knowledge confers, have been justly set forth by the author and publishers of this work in their respective prefaces. So also the propriety and facility with which this subject can be introduced among the instructions of the school-room, and rendered attractive to the young, is here fully explained. And these gentlemen may not be in error when they claim that theirs is the first treatise ever prepared in Great Britain, for the use of schools, upon this topic; yet, in the United States, there are several which are entitled to priority, one of which, first published in 1825, was by the present editor of this American republication, and has been extensively adopted, especially in the Sabbath-schools of this country. It did not, however, include animal physiology in general, but only that of the human body.

The present work will, however, be found to condense more extensive knowledge upon human and comparative physiology, within smaller compass, than any of its predecessors. Written by a practical teacher, actually engaged in the impartation of this species of knowledge to children, it has claims to peculiar merit. The illustrative drawings are well adapted to be transferred to canvas, and copied upon transparent media, on a magnified scale, as here recommended. But in this country we are happily furnished with extraordinary facilities of this character, in the splendid engravings on stone of Weber's Anatomical Atlas, by Messrs. Endicott of New York, who furnish them to schools at a very low rate. These drawings are so large, so accurate, and so beautifully coloured to nature, that they render the actual dissections here recommended in schools wholly unnecessary. Nor, indeed, would the public sentiment tolerate, in this country, the dissection even of inferior animals in schools, and especially in female schools. Nor is it at all called for, with the plates just named; which, indeed, have been brought out by the publishers here with special reference to the common schools of our state and country.

It is true that these plates are anatomical, not physiological; yet neither the teacher nor scholar can pursue the study of the animal functions to any extent, without an understanding of the structure of those organs upon which all the functions are dependent. Hence, anatomy and physiology are inseparable, and should be simultaneously cultivated, especially in schools. And with this book and Weber's plates alone, both sciences may be readily taught by any intelligent teacher, even though he or she may have heretofore neglected this study. It is mainly for the benefit of such that the analytical questions have been prepared, and will be found upon each page.

In using this book in schools, it is recommended that the teacher require the pupils to answer each of the questions in the language of the text, they having the book in the hand on going through it for the first time; but afterwards they should study a given number of pages in each lesson, and be prepared to answer the questions without the book. The ingenuity of the teacher will enable him to vary the questions and call for different examples and illustrations on each topic, and he should especially encourage the moral reflections which the marvellous works of God are calculated to inspire. The drawings, or models of human and animal structure, and of the important organs especially, will be found greatly to increase the attractiveness of the study.

That this book may serve to simplify the subject, and prompt to its more general introduction into the schools, is the hope and aim of

THE AMERICAN EDITOR.

SECTIONS.

EDITORS' PREFACE.

While it has been justly objected to popular medical guides and dictionaries, that, read under the influence of imperfect knowledge, they tend rather to mislead than to instruct, and probably induce more diseases than they cure, a candid mind must regard in a very different light the various works which have been published of late years for the purpose of conveying a popular knowledge of Animal Physiology. The sole and certain result of these must be, by giving a familiar knowledge of the human organization and its laws, to put individuals into the best possible condition for *avoiding* diseases—a very different thing indeed from the attempt to *cure* them. The utility of this knowledge to the non-medical community is now beginning to be generally felt, though still some perhaps require to be convinced of it. To such persons, it might be pointed out that, though almost all, from the communications made to them in childhood, or from their own sensations and experience, are enabled to observe some of the more obvious laws of organization—as, for a familiar instance, those respecting simple overloading of the stomach—there are others of those laws which most persons, for want of knowledge, are constantly breaking, to the great injury of their health. The general prevalence, amongst men of business, of an overtasking of the brain, amongst ladies of a neglect of out-of-doors exercise; the almost universal over-indulgence in stimuli of various kinds; and the tight-lacing of young females; are but a scantling of the errors which we everywhere see around us, as the result of a want of knowledge of the structure and functions of our physical frames. It is only, indeed, where the infraction of any organic law is followed very immediately by its appropriate penalty, as simple over-eating is by indigestion, that ordinary knowledge observes and records the fact. In the far more numerous, and generally much more important class of cases, where the effect is not to be readily traced to its cause, popular knowledge is completely at fault: nothing can there be of avail but a knowledge to some extent of the human organization and its laws. It may be true that the knowledge itself will not be sufficient to produce, in all, a proper attention to the rules of health; yet it is pretty clear that the knowledge *may* have such an effect, while, without it, nothing of the kind can be hoped for. It might also be expected, that, were a knowledge of our internal organization thoroughly familiarized and made present to every mind, public opinion would become engaged in causing individuals of a negligent disposition to observe the laws of health. It would be thought wrong for a man, having a family depending on himself, to expose his life to hazard by daily-endured mental exhaustion; and a young lady, entering a room with a waist reduced to half its proper circumference, would be shrunk from as a kind of monster. Thus knowledge would operate, not only in a direct way upon individuals, but through one individual upon another.

It is for these reasons, and under these hopes, that the Editors of the present Educational Course have long been deeply impressed with the propriety of introducing Animal Physiology as a branch of study into schools. It is, at the very least, a section of natural science of a most interesting and enlightening kind, in as far as it shows a basis in nature for many of our most familiar impressions, otherwise apt to be themes of wondering ignorance. For this reason alone, it might deserve a prominent place in every liberal course of study. But its most important end is to afford a knowledge of the laws on which *health* depends—that element in life without which no one can be useful or happy, while the want of it often becomes a spreading evil. "It has been objected," says an eminent writer on the science, "that to teach any one to take care of his own health is sure to do harm, by making him constantly think of this and the other precaution, to the utter sacrifice of every noble and generous feeling, and to the certain production of hypochondriacal peevishness and discontent. The result, however, is exactly the reverse; and it would be a singular anomaly in the constitution of the moral world were it otherwise. He who is instructed in and familiar with grammar and orthography, writes and spells so easily and accurately as scarcely to be conscious of the rules by which he is guided; while he, on the contrary, who is not instructed in either, and knows not how to construct his sentences, toils at the task, and sighs at every line. The same principle holds in regard to health. He who is acquainted with the general constitution of the human body, and with the laws which regulate its action, sees at once his true position when exposed to the causes of disease, decides what ought to be done, and thereafter feels himself at liberty to devote his undivided attention to the calls of higher duties. But it is far otherwise with the person who is destitute of this information. Uncertain of the nature and extent of the danger, he knows not to which hand to turn, and either lives in the fear of mortal disease, or, in his ignorance, resorts to irrational and hurtful precautions, to the certain neglect of those which he ought to use. It is ignorance, therefore, not knowledge, which renders an individual full of fancies and apprehensions, and robs him of his usefulness." * Another not less eminent writer says—"The obvious and peculiar advantages of this kind of knowledge are, that it would enable its possessor to take a more rational care of his health; to perceive why certain circumstances are beneficial or injurious; to understand, in some degree, the nature of disease, and the operation as well of the agents which produce it, as of those which counteract it; to observe the first beginnings of deranged function in his own person; to give to his physician a more intelligible account of his train of morbid sensations as they arise; and, above all, to co-operate with him in removing the morbid state on which they depend, instead of defeating, as is now through gross ignorance constantly done, the best concerted plans for the renovation of health." †

* Preface to Dr. Combe's Physiology.
† Animal Physiology, Library of Useful Knowledge.

As the present little treatise—the first ever prepared in this country for use in schools—is the production of a gentleman not only of respectable acquirements in the science, but who has had much experience in teaching it to popular audiences, the Editors have no doubt that it will be found peculiarly well adapted to its proposed end.

Edinburgh, October 14, 1839.

AUTHOR'S PREFACE.

The method of teaching Physiology in schools, which is recommended in this little treatise, originated from the following circumstances:—Some years ago, while the author was delivering, in Falkirk, a course of popular lectures on the science, he was waited on by the late Mr. Downie, teacher of English in the Falkirk Parochial School, who wished to receive an explanation of some parts of the lectures which he did not quite comprehend. Dr. Hamilton then learning from Mr. Downie that he had attempted to give his pupils some lessons on Digestion and the Circulation, immediately furnished him with his diagrams on these subjects, agreeing, at the same time, to examine, in a few weeks, the progress made by the pupils. This was done, accordingly, and Dr. Hamilton was astonished and delighted to find many of the boys well versed in the subject, and all the children evidently much pleased with explaining and copying the diagrams. After this period, instructions in different parts of Physiology were regularly given by Mr. Downie, with a success which can be appreciated only by those who witnessed the proficiency of his scholars. In giving these instructions, it has been found that the effectual way to interest the children, and to make them comprehend the necessary descriptions, *is to show them the parts to be explained.* When this is done, a thorough comprehension of

very intricate structures becomes quite easy; without it, Physiology never can be taught to children so as to be remembered.

It happens at present, however, almost universally, that before the pupil can be taught, the teacher must himself be instructed; and it is this circumstance that has induced the author to append, to each section of the present work, instructions to the teacher. These, it is hoped, will be found both simple and requiring little pecuniary outlay. Almost the only instruments required to make the preparations directed, are, a scalpel or good penknife, a pair of forceps (both to be had from the surgical instrument makers), and a saw. Let the teacher only "put his hand to," and he will find that a few trials will make him quite an adept.

Numerous wood engravings have been interspersed with the text. The teacher should have copies of the principal of these made, of a large size, without letters of reference, to exercise the pupils. A good and very cheap mode of making large diagrams, is to get a frame of the size wished, and to stretch upon it strong smooth machine-made brown paper.* Give this a strong coat of whitening and size (or glue), and, when dry, draw the figures with water-colours and size, of whatever shades are desired. Then cut them off the stretching frame, and nail them, at the top, between a piece of tape and a slip of wood to hang by, and between tape and a roller below. When smaller drawings are wished, different coloured chalks and cartridge or drawing paper may be used, giving them afterwards a coating of isinglass or skimmed milk. A good size for the larger sheets of diagrams (which are in general preferable) is four feet by six; and a good colour, where particular parts are not required to be distinguished, is burnt umber, to be had from any house-painter.

Additional figures and information may easily be had by referring to Dr. Combe's Physiology, Dr. Roget's Bridgewater

* Furnished by Cowan, paper-maker, Edinburgh, at 4d. per yard, four feet broad, and of any length. In stretching, the sheet should be damped with a sponge, pasted on the frame, and then a hot smoothing-iron passed along the pasted part to dry it first.

Treatise, Dr. Smith's Philosophy of Health, Animal Physiology in the Library of Useful Knowledge, Bell's Anatomy, Edwards's Elemens de Zoologie, Fletcher's Rudiments of Physiology, Caldwell on Physical Education, Prout's Bridgewater Treatise, Bell on the Hand, Brigham on the influence of Mental Excitement on Health, and the various elementary systems of Physiology, &c. To the work of Dr. Edwards the author has to acknowledge himself indebted for many of the illustrations in the following pages.

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ANIMAL PHYSIOLOGY.

SECTION I.

ORGANIZATION—LIFE. CLASSIFICATION OF ANIMALS.

[ANATOMY is chiefly the subject of the following section, and for the reason that this lies at the foundation of Physiology. The learner should, however, first become familiar with the signification of these and collateral terms.

Anatomy may be defined, the science of organization in the healthy or physiological state. It is called *Human* anatomy, when restricted to the structure of man; *Comparative* anatomy or Zootomy when it includes the inferior animals, and *Vegetable* anatomy when it teaches the structure of plants.

Physiology may be defined strictly as the science of nature, and hence it was originally synonymous with Physics, or Natural Philosophy, and comprehended both animate and inanimate beings. This term is now, however, restricted to signify living organization, or the functions of living bodies; literally, therefore, the science of life, or *living anatomy*. It is hence subdivided into Animal and Vegetable Physiology, the former of which only is the subject of this volume.

Until very lately, "the three kingdoms of nature," *animal*, *vegetable*, and *mineral*, were uniformly considered separately. The two former, however, being endowed with life, and analogous to each other in many respects, both by structure and function, are now classed together as the *organic* kingdom, in contradistinction to the *inorganic* world, which comprises the mineral kingdom.]

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1. All natural objects are therefore divided into two great classes, called the Organic and the Inorganic, the distinctive properties of each of which are in general readily recognised, but not easily explained. When the structure of animals and plants is attentively examined, parts are found to be included, to each of which some function or office has been assigned. To these parts the term *organs* has been given, and the whole structure is consequently said to be organized. Thus the heart and stomach of an animal are called organs, their functions being to circulate the blood and digest the food. Animals and plants are hence said to be Organic Bodies. Inorganic bodies are such as rocks, air, water, &c., which do not possess a structure of the kind mentioned.

2. Organic bodies both possess different qualities from the inorganic, and fulfil different purposes in the economy of the world. Animals and plants are of certain determinate kinds, each kind having certain peculiarities, and each individual of each kind passing through a certain routine of existence, from what may be called its *birth* to its *death*. In the first place, *life* is indispensable to the existence of an animal or a plant. Of this quality we know little more than that it is one which appears essential to organization, and that, while it is present, organic bodies are able, apparently through its means, to resist the action of various agents which would alter or decompose them if dead. Being in possession of the quality called life, a plant or animal commences the routine of existence—takes in nourishment from food and air, by virtue of which it grows to maturity—is afterwards supported for a certain space by the same means—and finally, when its purposes in the world have been fulfilled, and it has reached the term allotted to its species, it ceases to live, and is resolved into the elements of which it was formed. In addition to these peculiarities, which attend plants and animals in

1. Define organic and inorganic, organ and function, with examples of each.
2. Name individual bodies belonging to the organic and inorganic world.
3. Points of analogy between plants and animals.
4. Distinctions between plants and animals.

common, animals possess parts, which give them what is called *sensibility*, and which enable them to fulfil certain purposes of a character quite apart from those fulfilled by plants. In organic bodies, wherever there is sensation or voluntary motion, we have an animal; where these are wanting, a vegetable. Bichat, an eminent French anatomist and physiologist, has shown still further that this distinction forms a natural division of the complex parts combined in the animal system. Such parts as the heart, the intestines, &c., which act in general independently of our will, and without our consciousness, belong to what he calls the vegetative or organic life. The senses and parts that bring us into relation with our fellow beings and the external world, he calls the animal life. The division is so natural and comprehensive, that it has been adopted by almost all the best writers since the time of Bichat.

3. Animals, as well as plants, are distinguished from each other by peculiarities in their structure, some being of very simple forms, and possessing few organs or parts, while others are complicated in their figures and structure, and exercise a greater number of functions. Something like a regular progress or gradation has been observed from the most simple up to the most complicated, and the distinctions observed between different groups of animals have given rise to *classification*, or an arrangement for scientific purposes. The best existing classification is that formed by Baron Cuvier, usually called from its author the *Cuvierian System*, of which the following is an outline:—

4. The Cuvierian System supposes four Divisions of the Animal Kingdom, the first and simplest being the RADIATA, so called because some of the more remarkable creatures embraced by it have a rayed or branched figure. At the time, though it is still recent, when Cuvier formed his system, the animals placed by him in this division had not been very attentively observed; and it is probable

5. The doctrines of Bichat.
6. Differences between animals.
7. Whose classification?
8. His first division and the objections to it.

that, as they become better known, the propriety of classifying them otherwise will be acknowledged. Cuvier represented them as composed of a simple homogeneous pulp, movable and sensible, without any apparent apparatus for the senses; whereas parts different from pulp, and parts which some naturalists consider an apparatus for the senses, have since been in many cases ascertained.

5. The first of the so-called Radiata demanding attention are the Animalcules, or microscopic animals, so named as being only observable by means of the microscope. Apparently the simplest of these, and of all animals, is one termed the Monad, which seems to consist of merely a small round speck of animated matter, but is nevertheless found to possess at least organs of nutrition. It is one of a large class of animalcules, found in water in which decaying vegetable or animal matter has been infused, and thence called *Infusoria*, or Infusory Animals. Some of these are small to a degree which the mind cannot conceive, being only the 24,000th part of an inch in diameter, and yet possess organs for feeding, breathing, and volition or will. Many hundreds of varieties have been described or classified by Professor Ehrenberg of Berlin, who has also discovered that large strata of siliceous or flinty rock under the earth's surface are composed of the hard parts of these minute creatures, no doubt deposited in remote ages from large bodies of water filled with them.

6. The Hytadid (Fig. 1), a parasitic worm, found in the human and other bodies, is larger, but has also a very simple structure. It has a head with four suckers, and a neck communicating with a bag, which forms its stomach. This sac, when distended with fluid, nearly obliterates the neck, and the animal


Fig. 1. Hytadid.

9. Describe the first of these, and their different names.
10. What is wonderful in these?
11. Define parasitic.

then forms simply a globular bag. One species of this creature is sometimes found in the brain of the sheep, and gives rise to the disease called by shepherds *sturdy* or *staggers*. These bodies are so exceedingly simple, that it has been doubted whether they really are animals. An opportunity was afforded to many gentlemen in Edinburgh, a few years ago, of seeing a girl with one about the size of a pea within the ball of her eye, in which spontaneous motion appeared manifest. When at rest, it was nearly globular, but every few seconds it elongated itself into something like the form of a bottle of India-rubber.

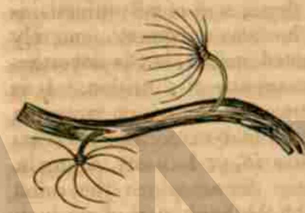
Fig. 2. Polype.

7. Of a structure a little more complex is the fresh-water Polype, of which two specimens, perched upon a stalk, are presented in Figure 2. It consists merely of a tube, with arms or tentacula at one extremity, with which it seizes small worms or insects, and conveys them into its interior to be digested: but of so little importance is the surface used for this purpose, that the animal may be turned inside out, like the finger of a glove, without apparently suffering the slightest inconvenience. It may also be cut into numerous pieces, when each separate piece will become a distinct animal; or parts of one polype may be grafted on the body of another.


Fig. 3. Star-fish.

8. The Star-fish (Fig. 3), a well-known creature, often found on the beach when the sea has receded, is among the highest of the Radiata. In it we find a stomach distinct from the mass of the body, and teeth surrounding its entrance. We find, likewise, for the first time, parts having the form

12. Describe the hytadid.
13. What of the polype?
14. Describe the star-fish.

of feet, used in progression. In the five rays there are no less than 1520 feet of a very curious construction.

9. The next division is denominated MOLLUSCA (molluscous or pulpy animals), in which we find, gradually more and more developed, organs used for progression, a stomach and intestinal canal, a heart, and organs for breathing, as well as several of the senses. Indeed, in some respects the higher orders of this division are superior to the articulated animals which have been placed above them. In their senses and instincts, however, they are generally much inferior. The Oyster, Mussel, and different kinds of snails; the Clio Borealis, a small animal found in multitudes in the northern seas, and which forms the principal food of the Greenland whale; the Nautilus (Fig. 4); all belong to this division. The Sepio or Cuttle-fish (from which the paint of this name is got) is one of the highest of the molluscous division, being possessed of vision and several other senses, as well as a heart; besides parts that serve either as powerful arms for seizing its prey, or feet for walking with.


Fig. 4. Nautilus.

10. The third division includes the Articulated or Jointed Animals (ARTICULATA), which, like the Mollusca, may be said to be intermediate between the Radiated animals and the highest division, or Vertebrata. The Radiata and Mollusca are generally aquatic, and limited in their powers of motion, but the Articulata have often a very complete motive apparatus. Among them also are found all the senses, and, for the first time, a symmetrical form of the body, or that


Fig. 5. Pontobdella.

15. The second division of the Cuvierian system.
16. Describe these with examples.
17. What is the third division called?

form in which two similar halves appear to have been, and really were, at one period of their growth, joined together. This form likewise obtains in man and all the higher classes of animals. In the Articulata, the solid parts or skeleton are always placed external to the rest of the body. The Pontobdella, a species of leech (Fig. 5), is a good example of a class of the Articulata, whose bodies consist of a succession of rings. The Crab (Fig. 6), the Spider, the Bee, Beetle, and Butterfly, are other specimens of this division.


Fig. 6. Crab.

11. The fourth and last division includes a vast series of animals, among which are seen the most elaborate exertions of creative power. The members composing it vary exceedingly in their instincts, appearances, and other peculiarities, but all agree in possessing an internal skeleton. In the simplest form in which this skeleton ever appears, the vertebral column, or back-bone, as it is usually termed, is always present; and hence this, by far the most interesting and best defined division, has been called the VERTEBRATA. In such fishes as the lamprey, the back-bone is merely a continuous soft tube, with slight divisions marked upon it; but as we ascend in the scale, these divisions become more decided, until we arrive at the separate and solid vertebræ of man and the higher animals.

12. Fishes are placed at the bottom of the series of Vertebrata—Reptiles next—then Birds—and finally Mammalia, or suck-giving animals, at the head of which is the human race. Although less highly organized in other respects, fishes have a skeleton of superior character to some of the class of reptiles, which is in some instances very slightly developed. The skeleton of the serpent,

18. The points of difference among these.
19. Give examples of these.
20. What is the fourth and last division?
21. Name the fourth subdivision of these.
22. Describe their peculiarities of structure.

one of the class of reptiles, is of a simple structure, though comparatively of great length. It consists merely of a vertebral column with ribs, and a head but slightly developed; but the vertebræ, or little bones composing the spine or vertebral column, are uncommonly numerous, being in some species three hundred, while man has but twenty-four, and the frog only eight. As we rise to higher orders, the offices of the vertebræ become subdivided, and new parts are added, for moving, and for seizing or holding objects (in scientific language, for progression and prehension), suitable to the wants of each species.

13. In the Mammalia, the division of the skeleton into its different regions is complete. Figure 7 is the skeleton of a man, the highest order of the class. At the top we have the solid skull, to enclose and protect the important brain; the neck (*a'*) invariably composed, in this class, of seven vertebræ,* showing the uniformity of nature's plan in forming different families; the dorsal vertebræ, or vertebræ of the back, with the attached ribs (*r r*) and breastbone (*x*), constituting the chest or thorax, to which the anterior extremities are attached; below these, the lumbar vertebræ (*a*), forming the posterior boundary of the abdomen or belly; and, lower still, a strong circle of bones called the pelvis (*s s*), for connecting the inferior extremities with the trunk, and for supporting the bowels. In most of the Mammalia the vertebral column is still farther prolonged in the form of a tail, but in man it terminates by forming the posterior boundary of the pelvis.

[As the human skeleton here represented is one of the most interesting objects of study for young people, it is desirable that one should be procured for exhibition in every school in connection with anatomical and physiological instructions. The following additional items of information should be imparted upon this subject.

A natural skeleton is one in which the bones are con-

* The sloth appears, but only appears, to be an exception.

23. Define "progression and prehension."
24. To which series does man belong?

Fig. 7. Human Skeleton.

a' a, vertebral column, on the top of which is the cranium. *r r*, ribs, most of which meet in the sternum, or breast-bone *x*, so as to form the thorax. *y y*, the clavicles, or collar-bones. *b*, the humerus, or upper arm-bone. *c*, the elbow. *d*, the radius. *e*, the ulna. *f*, the wrist-bones. *g*, the phalanges, or finger-bones. *s s*, the bones of the pelvis. *w*, the sacrum. *h i*, the thigh-bones. *l*, the patella, or knee-pan. *m*, the tibia. *n*, the fibula. *o*, the ankle. *p*, the metatarsal or foot bones.

25. Describe the human skeleton, as here explained.

nected by their ligaments; but when joined by wires, it is called an artificial skeleton.

The number of bones in the body of an adult are two hundred and eight, besides the thirty-two teeth and the eight little bones found in the thumb and great toe, being two hundred and forty-eight in all, though some reckon two hundred and fifty-two, by distinguishing parts of the same bones.

The human skeleton is usually divided into the head, trunk, and extremities.

In the *head*, there are sixty-three bones, including thirty-two teeth, and of these eight belong to the skull, eight to the internal ears, fourteen to the face, and one to the tongue.

In the *trunk*, fifty-three bones are found, viz. twenty-six to the spinal column, twenty-five to the thorax or chest, and two to the pelvis, or basin found at the base of the trunk.

In the *superior extremities*, there are sixty-four bones, including the arms, hands, and fingers; and sixty in the *inferior extremities*, comprising the legs, feet, and toes; the sesamoid bones of the thumb and great toe being counted.]

14. These parts are variously modified in different species; but the general remark may be made, that the organs of each are connected so closely as to enable an anatomist to tell with certainty, from seeing a single bone, or even a part of a bone, the general form and habits of the animal to which it belonged. This may appear almost incredible, but may easily be illustrated by an example. Let us suppose a properly qualified person to find the broken off lower extremity of the bone called the radius (Fig. 7, *d*). He could easily tell, from examining its articulations, whether it was intended to be movable or fixed. If fixed, as we find it in the horse or cow, then he would infer that it served as a solid support to the body, but was not meant to be used in seizing objects, as in man, the cat, monkeys, &c., in all of which it is movable. But if the animal did

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26. Can the form of an animal be conjectured by a single bone?
27. What illustration is cited, and what inference is authorized?

not seize objects, it could have no use for claws, and would undoubtedly in their stead have hoofs. Hoofs, again, always imply a vegetable feeder, with grinding teeth, a particular form of alimentary canal, a certain conformation of the spine, &c.; so that it will thus be seen, that, from this broken piece of bone, a good general idea of the size, form, and habits of the animal, might be formed.*

15. Such reasonings as the above, it will be observed, are all grounded upon the supposition that the animal frame has been put together upon rational principles. This will become abundantly evident as we proceed with our subject. We shall quickly discover that no organ stands isolated, but that each has intimate relations with the rest, always forming a harmonious whole; and that, whether we examine the structure of the individual parts, or their relations, we must equally feel that all has proceeded from the hand of an infinitely wise and good Creator.

A proper acquaintance with the classes of the vertebrata is so important, that we have appended the following table of their chief characters, taken from Edwards's "Elemens de Zoologie," an admirable work for the student of natural history. The teacher should have these tables transcribed on a large scale, and as the pupil gains a knowledge of the different organs, exercise him in the details by frequent examinations. In order, also, to render more intelligible our allusions to Cuvier's classification, we have given a condensed view of the vertebrate classes and orders, with examples.

An excellent plan for impressing on the minds of children Cuvier's four great divisions of the animal kingdom, is to make a large diagram, with drawings of each placed under their respective heads. Numerous appropriate figures may be found in Dr. Roget's Bridgewater Treatise, vol. i., pages 165, 227, 258, 271, 283, 411, 441, 447, 530; in Grant's Comparative Anatomy; and in Edwards's Zoologie, &c.

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* Dr. Buckland, in his Bridgewater Treatise, relates a fact admirably exemplifying what has been stated. A good many years ago, a few of the bones of an extinct species of animal had been found, before the general form of the animal was known. From these bones, Mr. Connybeare, a celebrated geologist, set himself to construct an animal such as he supposed that to which the bones belonged would be. Some years afterwards, a complete skeleton of this singular animal, the Plesiosaurus, was discovered, with which Mr. Connybeare's drawing was found in a surprising degree to correspond.

OUTLINE OF CUVIER'S CLASSES AND ORDERS OF THE VERTEBRATA.

CLASS I.—MAMMALIA.

Order.

1. Bimana (two-handed). Man.
2. Quadrumana (four-handed). Monkey, Ape, Lemur.
3. Carnaria.
   - Cheiroptera (wing-handed.) Bat.
   - Insectivora (insect-eating). Hedgehog, Mole.
   - Plantigrada (foot-walking). Bear, Badger.
   - Digitigrada (toe-walking). Dog, Cat, Lion, Weasel.
   - Amphibia (doubtful, or belonging both to sea and land). Seal, Walrus.
4. Marsupialia (pouch-nursing). Kangaroo, Opossum.
5. Rodentia (gnawing). Rat, Hare, Beaver, Squirrel.
6. Edentata (wanting teeth). Sloth, Ant-eater, Armadillo.
7. Pachydermata (thick-skinned). Horse, Elephant, Hog.
8. Ruminantia (cud-chewing). Ox, Deer, Sheep, Camel.
9. Cetacea (whale-like). Whale, Dolphin, Narwhal.

CLASS II.—BIRDS.

1. Accipitres (hawk-like). Eagle, Vulture, Owl.
2. Passeres (sparrow-like). Sparrow, Thrush, Lark, Crow, Swallow.
3. Scansores (climbers). Parrot, Cuckoo, Woodpecker.
4. Gallinæ (hen-like). Peacock, Pheasant, Pigeon.
5. Grallæ (stilt-legged). Stork, Snipe, Plover.
6. Palmipedes (web-footed). Duck, Goose, Swan, Pelican.

CLASS III.—REPTILES.

1. Chelonia (tortoise-like). Tortoise, Turtle.
2. Sauria (lizard-like). Crocodile, Lizard, Chameleon.
3. Ophidia (serpent-like). Viper, Boa, Serpents.
4. Batrachia (frog-like). Frog, Newt, Salamander.

CLASS IV.—FISHES.

1. Acanthopterygii (thorn-rayed). Perch, Mackarel.
2. Malacopterygii (soft-rayed). Salmon, Cod, Herring, Eel.
3. Lophobranchii (loop-gilled). Pike-fish, Pegasus.
4. Plectognathi (jaw-joined). Sunfish.
5. Chandropterygii (gristle-rayed). Shark, Lamprey, Sturgeon.

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28. What classes and orders in this table?

CHIEF CHARACTERS OF THE CLASSES OF THE VERTEBRATA.

MAMMALIA.	BIRDS.	REPTILES.	FISHES.
Viviparous.	Oviparous.		
With teats.	Without teats.		
Globules of blood circular.	Globules of blood eliptical.		
Blood warm.		Blood cold.	
Breathe by lungs.			Breathe by gills.
Respiration simple.	Respiration double.	Respiration simple.	
Circulation double complete.		Circulation double incomplete.	Circulation double complete.
Heart with four compartments.		Heart usually with 3 compartments.	Heart with 2 compartments.
Skin furnished with hairs.	Skin furnished with feathers.	Skin naked or furnished with scales.	
Members organized in general for walking.	Anterior members organized for flight.	Members organized in general for walking.	Members organized for swimming.

29. Enumerate the chief characters in the vertebrata.

SECTION II.

MASTICATION—DEGLUTITION—DIGESTION.

16. The details which follow, refer, for the most part, to the sciences of Anatomy and Physiology, the former of which treats of the structure of animals, the latter of their functions, or of those phenomena which are peculiar to life. It is chiefly of the Physiology of the higher Vertebrate Orders, and particularly of Man, that we design at present to give some account; and in doing this we shall keep in view the important division of Bichat, into the organic or vegetative, and the animal or relative functions, although a slight departure from it will occasionally be necessary, to give connection, and to prevent repetition.

17. The first, because the most essential, processes which engage our attention, are those which relate to the introduction of food into the body, its digestion, and its assimilation.

18. It has hitherto been supposed that many of the lower and more minute creatures possess no cavity for the reception of nutriment, but are supported by the absorption of aliment through the outer surface. Of late, however, so many animals of this obscure kind, formerly thought stomachless, have been discovered to possess alimentary cavities, that it is now probable that no creature whatever is altogether deficient in a stomach. In the Infusoria, such an opening has been discovered, in some instances surrounded on the outside by *cilia*, or a series of hairs, the office of which seems to be to draw food towards the mouth. In the Polypes we find the orifice of the alimentary cavity surrounded in like manner by *tentacula*, or long string-like arms, with which they seize their prey, and convey it to its proper receptacle. In the star-fish the opening of the stomach is surrounded with teeth, and the cuttle-fish, of the division Mollusca, possesses, in addition

30. Define Anatomy;—and Physiology.
31. What processes seem most essential to life?
32. What is now probable in regard to the animal creation?
33. Name some of the varieties of structure.

to its numerous tentacula, a strong beak, like the parrot's, for crushing the shell-fish on which it lives. In Insects we find mandibles and a proboscis or trunk, with a thousand other modifications leading us up to the regular masticating apparatus of the vertebrate division.

19. This *masticating apparatus* consists of several parts. We have, 1st, the teeth for seizing or dividing the food; 2d, the glands which secrete the fluid for moistening the food and mouth; and, 3d, the tongue and other muscles which move the food from side to side, or carry it backwards to be swallowed.

20. From what was formerly said, it must be evident that the *Teeth* are parts of great importance to the zoologist. They at once give him decisive indications of an animal's habits, conformation, and other qualities. In the adult man they are thirty-two in number, and consist of four different kinds, namely, 1st, of eight incisors, or cutting teeth, in front; 2d, of four cuspidati (pointed), or canine teeth; 3d. of eight bicuspidati, or small grinders; and, 4th, of twelve molares, or proper grinders. The molares are flat-crowned in the horse, and in the other Herbivora, while the canine are either wanting, or, as in the horse, are rudimentary; that is, imperfectly developed. The canine are largely developed in the lion (Fig. 8), and in the Carnivora, or flesh-eating tribes, generally, which have also the molares pointed instead of flat.

Fig. 8. Bones of Lion's Head.

In insectivorous animals, such as the mole and hedgehog, the molares are formed as in Fig. 9; while in the shark (Fig. 10), and other fishes, which swallow their prey entire, the teeth are all of the same pointed form, and are numerously set, even on the lips, sides of the mouth, and throat.

Fig. 9.

Even the degree in which an animal is carnivorous, or otherwise, is marked very accurately by the more or less

34. What are included in the masticating apparatus?
35. What of the teeth?
36 Enumerate and classify the human teeth in an adult.
37. How in herbivorous and carnivorous animals?
38. How in the mole, and shark?

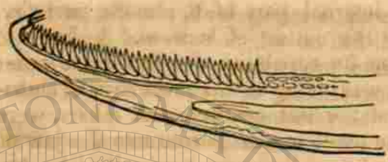

Fig. 10. Shark's Jaw and Teeth.

pointed form of the teeth. Thus, among the Carnivora, the lion and others of the cat tribe are found to have all the molares pointed except two, which are rounded; while ferrets and polecats have four, and dogs eight, rounded. The teeth of man seem to approximate him, in this respect, to families such as we find among the Quadrumana, or monkey tribes, which, in their natural state, live principally upon fruits, but do not refuse also various kinds of animal food.

21. Nothing can be more plain than nature's intention in thus varying the forms of the teeth. Without any exception, these variations have the most precise relation to the instincts of each tribe. It is quite impossible that the sharp teeth of the tiger or shark could ever be used for grinding food, like that of the cow or the horse, or that the teeth of the latter could be intended for seizing or tearing flesh; and this becomes still more striking, when we observe how the jaws in which the teeth are set have been articulated. In the Carnivora, as the teeth merely cut, the jaws are jointed like the blades of a pair of scissors; but the jaws of the Herbivora, and of Man, allow of a grinding motion. This motion, in the cow and horse, is from side to side, or nearly circular; in the Rodentia, as the rat, &c., the grinding motion is rapidly performed in a longitudinal direction.

22. The human teeth are composed principally of two substances, the *enamel*, and the *ivory*, or *bone*. The enamel is placed externally and on the body of the tooth, and forms only a thin layer. It has ninety-eight per cent. of earthy matter in its composition, and is so hard as to strike fire with steel, and is viewed by physiologists as void of vitality, so that when once formed, the teeth never increase in size, and when any part of the enamel is destroyed it is never

39. What indications may be drawn from the teeth?
40. What peculiarity in the form and motion of the jaws?
41. Composition of human teeth and the difference.

regenerated. The internal part of the tooth, or ivory, approaches more to the nature of bone, and is shown to possess vitality, from its capability of adhering to other vital structures. It was owing to this property that Duhamel, a physiologist of the last century, and others, were able to transplant the teeth of one person into the jaw of another, to make them grow upon the combs of cocks, &c. Transplanting sound for decayed teeth, threatened, indeed, at one time, to become but too common among the better ranks, until, happily for the interests of humanity, it was discovered that this practice produced disorders more serious than the deficiencies intended to be supplied.

23. Other animals have the enamel differently distributed. The horse, elephant, and other Herbivora, have layers of it which penetrate interiorly. These, from being harder than the surrounding ivory, are longer of wearing down, and hence form projecting ridges, of great importance in triturating their food. The incisors of the beaver, and other Rodentia, want the enamel posteriorly, and, for the same reason, wear soonest in that direction. As a consequence, they always preserve a sharp edge in front, which is of the greatest importance to this gnawing order.

24. The teeth furnish a beautiful example of what has been justly denominated a prospective contrivance. Their presence above the gums at birth would have been only an annoyance. Accordingly, they are then wanting; but nature, which anticipates our needs, places them deep in the jaw, even before birth, to appear in due season. If a section of the jaw of a young animal be made, some of the teeth may be seen just beginning to be formed—others cutting through the bone—while others are passing through their last covering, the gum.* In the child, the teeth generally begin to appear from the sixth to the twelfth month,

* [There is a slight inaccuracy here, for the teeth are not in the jawbone as here intimated. There is placed along the edge of each of the jawbones, a bony process which is covered by the gums, but which is distinct from the jaw. This bony structure contains the rudiments of the teeth, and seems to sprout out along with the teeth in

42. How is the vitality of the bony part proved? illustrations?
43. Peculiarities in certain animals.
44. What of the rudimental teeth in young animals?

and the first or milk teeth, twenty in number, are usually completed about the third year. These again begin to shed about the seventh year; and the second, or permanent set, is not complete until about the sixteenth or eighteenth year.

25. In the process of shedding, the crown, or that part of the tooth which is coming forward, presses upon the fang of the one already occupying the jaw, and causes its absorption. It is the impossibility of growth, in consequence of the non-vital nature of the enamel, which renders the renewal of the teeth necessary. In consequence, also, of the jaw, during youth, increasing its dimensions, mostly posteriorly, it is necessary that the number of the teeth should be increased, in that situation, in order that no part of the jaw may be unfurnished. For this reason, about the time when the human being reaches maturity, a new tooth rises at each extremity of the range, being four new ones in all, which, from the time of their appearance, are called the *wisdom teeth.* There are some teeth which animals of other species do not shed. The incisors of the Rodentia, and the grinders of the elephant, &c., continue to grow during the whole life of the animals.

26. The second part of the masticating apparatus, is that which moistens the food and mouth. The fluid employed for this purpose is tasteless, and is called *saliva.* It is produced by six bodies called glands, two of which are placed near the angles of the lower jaw (submaxillary), two under the tongue (sublingual), and one on each side, immediately before the ears (parotid). All these open into the mouth by means of small tubes or ducts—the four first under the tongue, the two latter on the inside of the

their growth to maturity, and is found to be absorbed after the teeth have been removed, as in advanced age, leaving the jawbone only covered by the lining membrane of the gums. This bony process is called the alveola, or alveolar process, into which the teeth are inserted, and being an appendage both to the teeth and the jawbone, it serves to impart great solidity to their attachment, and render their extraction difficult. The pieces of bone which sometimes come out with the teeth when awkwardly extracted, are not parts of the jawbone, but pieces of this alveolar process, or bony socket of the teeth The gum is the soft part covering this bony process.]

45. Describe the progress of teething in infancy.
46. Wherein is the wisdom of this arrangement seen?
47. How is the posterior part of the jaw supplied at mature years?

cheeks, opposite the second or third molar teeth of the upper jaw. The fluid trickling from the latter may be seen at any time by turning out the cheeks, and watching their small openings. Its flow is seen to be increased by pressing with the finger from the ear forwards. The camel is supplied with additional salivary glands in its throat, which are of great service in its long journeys over burning deserts. Fishes, again, from living in water, and masticating but little, do not require, and are therefore destitute of, salivary organs.

27. The muscles of the tongue, cheeks, &c., which bring the food under the influence of the teeth, and pass it backwards into the gullet, form the third and most curious part of the masticating apparatus. Indeed, this, which we shall examine in connection with *deglutition*, or swallowing, is undoubtedly among the most admirable and wonderful of the bodily processes. During the comminution of the food the mouth forms a shut cavity, bounded by the closed lips anteriorly, the cheeks laterally, and the root of the tongue and the curtain of the palate brought together posteriorly. In Fig. 11, which represents the throat or pharynx cut open behind, *d* is the curtain (*velum palati*), with its central dependent part called

Fig. 11. Back of the Pharynx cut open.*

* *a a*, the nostrils. *b*, the mouth. *c*, the tongue. *d*, the curtain of the soft palate. *e*, the glottis, opening into the windpipe. *g*, the epiglottis. *i*, the gullet. *k*, the windpipe.

48. What difference in other animals?
49. Describe the salivary apparatus, and illustrations.
50. How is the food passed into the stomach?

the *uvula*, and *c*, the tongue. When the food has been properly moistened, and broken down, it is rolled into the form of a ball, and is passed backwards by the tongue and other muscles into the *pharynx*, which may be conceived of as a kind of bag, having the nostrils (*aa*) opening into it from above; the *mouth* (*b*) opening below these; the *glottis* (*e*), and the *gullet*, or *œsophagus* (*i*), still lower; besides two other openings called *Eustachian tubes*, which open on its sides, and lead to the internal ear.

28. Before the food can get into the pharynx, the curtain (*d*), which we have said is, during mastication, applied closely to the root of the tongue, must be lifted up. But if nothing more were done, the food or drink might pass from the pharynx into any or all of the openings mentioned, the inconvenience attending which, every one has experienced when a morsel of food or a little fluid gets into the nostrils or the windpipe. This, however, is effectually prevented, for the curtain is not only lifted up, but is also instantly applied closely to the back of the pharynx, so as to cut off the communication with the nostrils, and close the Eustachian openings; while, at the same instant, the sides of the glottis, or opening into the windpipe (*e*), are drawn together, and a gristly substance, the epiglottis (*g*), is folded back over it. The food, being still forced backwards, passes rapidly over the epiglottis into the gullet (*i*), the only opening it can now escape by, and from it is carried downwards into the stomach.*

* It is exceedingly difficult for a person who has not made these parts and actions his study, thoroughly to comprehend them. The action of the curtain, perhaps the most interesting of the whole, may easily be exemplified in the following manner:—We have said first, that the mouth, during mastication, forms a shut cavity, the curtain being applied closely to the root of the tongue. The same takes place when the cheeks are distended with air. If the communication were not then cut off posteriorly, the air would escape by the nostrils. We may even feel the curtain forced back when the lips are kept firm and the distended cheeks are pressed with the fingers. Secondly, we have said that the curtain is lifted up and applied to the back of the pharynx during deglutition, in order to cut off the communication with the nostrils. To show that this is the case, attempt to swallow some fluid or saliva from the mouth, and at the same time keep the cheeks distended. This will be found impossible, because, the moment the curtain is lifted up, the compressed air escapes by the nostrils. As an example of the curtain being applied to the back of the pharynx, blow smartly through the mouth, when it will be found that not a particle of air escapes by the nose. The communication with the nose must therefore be cut off. Again, when we blow through the nose, though the mouth be kept open, no air will escape by it. The curtain must therefore be applied to the tongue; nay, while blowing through the nose, we may even see this in the mouth of another, or feel it with our finger in our own. Children born without curtain and palate never can suck, because they cannot make the mouth a shut cavity; and, in this case, or where these parts have been destroyed by disease, deglutition is always difficult.

To form a proper conception of the other parts concerned in deglutition, a preparation, like the one described at the close of this section, must be seen.

51. Describe the structure of the mouth and throat.
52. How is the food kept out of the nostrils posteriorly?
53. How is the windpipe protected?
54. Describe the act of deglutition.

29. Complicated as these different actions may appear, we know how accurately they are all performed many hundred times daily, in swallowing our saliva, and in taking food and drink. They may be divided into three kinds; first, those of the cheeks, tongue, and sometimes the curtain, which give us sensations, and are voluntary; secondly, those of the pharynx, which still produce a sensation, but which can be called into operation only when the food or drink comes into contact with the pharynx;* and, thirdly, those of the gullet, which are performed almost entirely without our consciousness.

30. In the examples hitherto adduced, we have found mastication to precede deglutition. Other animals, however, swallow their food first, and comminute it afterwards. This is the case with the lobster, the grasshopper, &c., which have their teeth immediately connected with

* The simple experiment of swallowing our saliva several times in rapid succession, illustrates this well. As long as there is saliva to come into contact with the pharynx, deglutition can be performed; when the saliva is exhausted, our power over these parts is gone. Mr. Mayo thinks the muscles in this case are fatigued and cannot act. This is evidently incorrect, for they instantly act again with ease when saliva is furnished.

55. How many and what organs are employed?
56. Are all voluntary actions?
57. Illustrate those that are involuntary.

their stomachs. One species of the latter has no fewer than two hundred and seventy teeth. The same purpose is served by the gizzards of granivorous birds, only that the grain is ground between two hard horny surfaces, which act like millstones, their effect being increased by numerous small stones swallowed instinctively by the animal. As many as two thousand of these stones have been counted in the gizzard of a goose.

31. The processes which have been described are all preparatory to the *digestion of the food*, and this takes place in the stomach and intestines. Substances received into the stomach as food must necessarily undergo many changes in their composition before they are fitted to form part of the animal body, but the extent of the change required is proportionate to the difference between the qualities of the nutritive materials in their original and in their assimilated states. Thus, the conversion of vegetable into animal matter necessarily implies a more lengthened process, and a more complicated apparatus, than the assimilation of what has already been animalized. The cow eats grass, and converts it into flesh, by passing it through a series of very complicated organs; and we, in our turn, eat the flesh of the cow, and convert it into the substance of our bodies, but we employ for this purpose a much less complex machinery. As a substitute for such assistance as the cow lends in this case, man has invented the art of cooking, by which he is enabled to extract nourishment from substances that to him in their natural state are quite indigestible. Hence he has much greater variety in his food than any other animal.

32. The agent which nature employs to bring about the decomposition of the food when it arrives at the stomach, is called the *gastric juice*. When milk is taken into the stomach, the active principle of the gastric juice immediately separates the fluid from the solid parts, and this is

58. What animals swallow before mastication? and why?
59. What instinct of certain birds is remarkable?
60. What is said of digesting vegetable and animal food?
61. What of the cow.
62. What of the gastric juice.

the reason why milk is always curdled when it is vomited. This principle in the calf's stomach, called the runnet, when infused, is used for the same purpose in dairies.

33. A good many years ago, Dr. Stevens of Edinburgh showed very satisfactorily the action of the gastric juice on various substances, by enclosing these in silver balls, perforated with holes, which were swallowed by an itinerant German, who went about exhibiting the singular power he had acquired of swallowing stones, &c. In one of these balls, divided by a partition, were enclosed four and a half scruples of raw beef, and five scruples of raw fish. In twenty-one hours the beef had lost one and a half scruples, and the fish two scruples. In another ball was placed some beef which had been previously chewed; and in thirty-eight hours after it had been swallowed, it was found quite empty. The balls, in other experiments, contained pieces of roasted turkey, boiled salt herring, raw potatoes and parsnips, and apples and turnips, both raw and boiled, which disappeared in thirty-six hours. He also enclosed in the balls live leeches and worms, which were found, upon examination, not only dead, but completely dissolved. Most probably they were first killed by the high temperature of the body, and were then acted on by the gastric juice, for we observe that this fluid has no action on a body as long as it retains its vitality. Different kinds of worms which naturally inhabit the stomach and intestines, remain free from its influence so long as they are alive, but whenever they die, they are either digested or evacuated. In accordance with the same law, there is the curious observation made by Mr. John Hunter, the truth of which has since received repeated confirmations, that the gastric fluid actually, in some cases after death, dissolves and perforates the stomach itself and surrounding structures. Dr. Stevens, in another series of experiments, found that the gastric juice of dogs produced no effect upon vegetables, but easily dissolved flesh, bones

63. Describe Dr. Stevens's experiments, in the stomach of a German.
64. Mr. Hunter's observation.
65. Dr. Stevens's experiments.

and even ivory, while the same fluid in the sheep or the ox made no impression on beef, mutton, or other animal bodies, but acted energetically on vegetable substances.

34. Dr. Beaumont, of America, enjoyed a rare opportunity of observing the qualities of the gastric juice, and the process of digestion in the human body. A young Canadian, called Alexis St. Martin, who had received the contents of a musket in his left side, after recovering from the effects of his wound, had an opening left into the stomach, through which its operations and contents could be seen and examined. At first this opening was attended with inconvenience, but afterwards a fold of the stomach became fitted to it and filled it up, acting like a valve, so that it could be pushed inwards at pleasure. Dr. Beaumont having hired this young man as his servant, made a most elaborate and careful series of observations on different parts of the digestive process, which he has published, and which are well worthy of a perusal. To show the properties and action of the gastric juice, we shall here state a few of these. It had been noticed by previous observers that the fluid obtained from the stomachs of animals is sometimes not in the least acid; but Dr. Beaumont has shown, that though this fluid may show no acidity at other times, during digestion, or even when the stomach is mechanically irritated by an India rubber tube, the bulb of a thermometer, &c., it is always acid; and the acidity which is caused principally by a small quantity of muriatic acid (spirit of salt), appears to be essential to the proper performance of digestion. Dr. Beaumont frequently obtained at one time as much as an ounce of the gastric juice, which appeared to him to be poured out into the stomach of his patient by numerous minute clear points. He says it is a clear transparent fluid, without smell, slightly saltish, and very perceptibly acid. Its taste resembles that of thin mucilage, slightly acidulated with muriatic acid. It undergoes putrefaction with difficulty, and checks its progress in other animal substances. In

66. Dr. Beaumont's patient, and experiments.
67. Describe the gastric juice, and its effects upon food.

one of the experiments, St. Martin dined at one o'clock on roast beef, bread, and potatoes. In half an hour the contents of the stomach were found to be reduced to a mass resembling thick porridge, and by six o'clock the whole had been dissolved and carried out of the stomach. In other experiments, Dr. Beaumont shows that vegetables are much more rapidly dissolved than animal substances, and some of the latter more quickly than others of the same kind. Thus, fried tripe was digested in one hour; boiled cod, and likewise bread and milk, in two hours; roasted beef, and also soft-boiled eggs, in three hours; salted pork in four and a half hours; hard-boiled eggs in five and a half hours; and an unusually full meal of salted pork required six hours for digestion. Other experiments, similar to those of Dr. Stevens, were also made, in which St. Martin breakfasted on fried sausages with coffee and bread, while portions of the sausage, enclosed in a muslin bag, were placed in the stomach. In three hours the stomach was half empty, and the contents of the bag about half diminished; and in five and a half hours the stomach was empty, and the bag contained only a few small pieces of gristle, and the spices of the sausage.*

35. We have occasionally examples of the power of the gastric juice over still more solid bodies. Cuvier opened the stomach of an ostrich, which contained nearly a pound of bits of iron, copper, pieces of money, &c., corroded and worn down by attrition. Even the human stomach has a similar power, though less frequently called upon to exercise it. An American sailor, who died in one of the London hospitals in 1809, had swallowed during the ten previous years no fewer than thirty-five clasp-knives.

* The gastric fluid has been found equally to produce its specific effects when substances are submitted to its action out of the body. It has lately been ascertained that a fluid very similar in its properties, may be produced by mixing the dissolved mucus of the stomach with a little muriatic acid. The mixture possesses different properties from either fluid singly. A brief account of the case of Alexis St. Martin is given in Dr. Combe's work on Digestion, and in Mayo's Physiology, and a larger account in a separate volume is published by Dr. Beaumont in America, and republished in this country by Dr. Combe

68. Illustrate the power of the gastric juice by examples.

Corroded fragments of upwards of thirty of these were found in the stomach after death. Other cases of the same description have since been recorded.

36. The intestinal canal is divided into the *stomach* (Fig. 12, *b*), *small intestines* (*d d*), and *large intestines* (*e e e*); all of which are contained in the abdomen or belly,

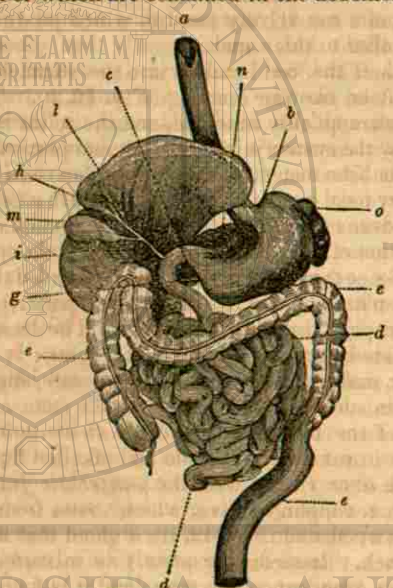

Fig. 12. Stomach and Intestines.*

and are seen in their natural situation in Fig. 21. They are all composed of three coats. The outer or serous coat is the smooth surface we see on opening the belly of an

* *a*, the gullet. *b*, the left or cardiac extremity of the stomach. *c*, the right or pyloric extremity of the stomach. *d d*, the small intestines. *e e e*, the large intestines. *g*, the duodenum or commencement of the small intestines. *l*, the liver. *h*, the duct from the liver. *m*, the gall bladder. *i*, the common duct. *n*, the pancreas or sweetbread. *o*, the spleen.

69. What division is made of the intestinal canal?
70. Describe the mesentery.

animal, the two layers of which unite behind the bowels to form the mesentery (Fig. 13, *c c*), which attaches the intestines to the back-bone; the middle is the muscular coat, which produces what are called the peristaltic or vermicular (worm-like) motions, which take place in the propulsion of the food downwards; the inner is the mucous coat, of a soft velvety texture, which produces all the fluids peculiar to this canal.

37. When the food is taken into the stomach, it enters by the left or *cardiac* opening (Fig. 12, *b*). The more fluid parts are quickly absorbed, and the solids begin to be acted on by the gastric juice. A moderate portion of animal food, as has been stated, is dissolved in about two hours, and an ordinary meal generally in about double that time. As the solution advances, the dissolved parts are gradually moved by the action of the stomach towards the right opening (*c*). This portion is thicker than the rest, and is called the *pyloric orifice*, from its supposed resemblance to a porter, in preventing the escape of the undissolved food. The dissolved food, here gathered, receives the name of *chyme*; it is a grayish, pulpy matter; always, in a healthy state, slightly acid. It passes in successive portions, from the stomach into the first part of the intestines, called the *duodenum* (Fig. 12, *g*), where it mixes with the bile and alkaline fluid poured out by the *liver* (*l*), and with the *pancreatic juice*, a fluid somewhat resembling saliva, which comes from the *pancreas*, or sweetbread (Fig. 12, *n*), a gland that lies behind the stomach. Immediately after this mixture, an alteration takes place upon the mass, and it is found to separate into two parts, one of which is carried out of the system by the bowels,* while the other, called the *chyle*,

[* This process by which the useless portion of the food is carried off is called excrementitious, and is indispensable to health. The bile secreted by the liver, appears to be the agent specially active in propelling this rejected mass downward, and upon the healthful condition of the bile, both in quantity and quality, depends the regularity by which this function is performed. The peristaltic motion of the bowels seems to be produced by the bile, and when this is absent, a substitute has to be found in some drug of similar properties, to overcome or prevent constipation.]

71. The coats of the intestines.
72. What propels the food downwards, and what is it called?

or the nutritious part of the food, is taken up, principally from the small intestines, by innumerable minute vessels. These have received the name of *lacteals*, from the milk-white appearance they present when extended with chyle, and they are said to terminate on the inner or mucous coat of the intestines by open mouths. Figure 13 shows the lacteal vessels (*b b*) coming from part of the small intestines named the *jejunum* (A). The membrane *c c*, named the mesentery, is that by which the intestine is confined to the spine. The lacteals have a beaded appearance, from the valves with which they are thickly furnished to prevent the return of the chyle. This fluid,

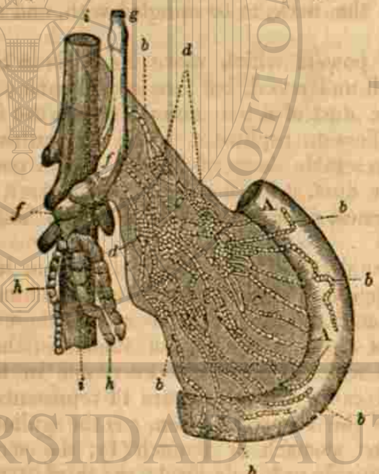

Fig. 13. Lacteals and Jejunum.

A A, a portion of the small intestines (jejunum). *b b b b*, lacteal vessels. *c c c*, the mesentery. *d d*, mesenteric glands. *f f*, the receptacle of the chyle. *g*, thoracic duct. *h h*, lymphatic vessels from other parts of the body. *i*, the aorta.

73. Name the two openings of the stomach, and relations.
74. What becomes of the fluid and then of the solid food?
75. What is chyme?
76. Where does the food pass from the stomach, the chyme?
77. What fluids does it mix with there, and what takes place?
78. What vessels take up this chyle, and in which intestine?

in passing through them, traverses small bodies called mesenteric glands (*d*), in which it probably undergoes some alterations. As it advances, the lacteals unite more and more, until they terminate in a vessel called the *receptacle of the chyle* (*f*), where the chyle mixes with *lymph*, a fluid brought from other parts of the body. In the accompanying engraving, other absorbing vessels (*h h*) are seen coming from other parts of the body, also to unite in the receptacle of the chyle. The compound of lymph and chyle then passes through the terminating branch of this system of vessels, called the *thoracic duct* (*g*), a little larger in man than a crow-quill, and by it is poured into veins near the neck, to be mingled with, and to become, the blood.

38. The powers which move the chyle in this course are not well understood, but are considerable; for when the thoracic duct of a live animal is tied, the force from behind suffices to rupture it. The properties of chyle somewhat resemble those of blood. When poured from the thoracic duct, it has a slightly pink colour, and, like blood, separates, upon standing, into a solid and a watery part.

39. These details may serve to give some idea of the process of digestion in man, and animals like him. Among the Ruminantia, or those animals which chew the cud, there is not one, but a series of stomachs, the curious structure of which is familiar to every one in the article of our food called tripe. Figure 14 represents the four stomachs of the sheep cut open, *e* is the gullet opening into the first stomach or paunch (1); the second (2) is called the reticule or king's hood; the third (3) the many-plies; and the fourth (4) the red, which is the only one having an inner surface like the human stomach. P shows the situation of the pylorus. The Ruminating family possess a voluntary power over their stomachs, which we and most other animals want. They are able, at pleasure, to bring up, into their mouths, the food which

79. Where and how is it then carried, and what mixture takes place?
80. By what vessel does it pass into the veins, and meet the blood?
81. Does the chyle resemble blood?

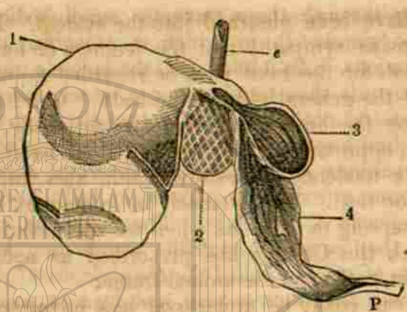

Fig. 14. Section of Stomachs of the Sheep.

has been macerating in the fluids of the paunch and king's-hood, to be again masticated. They then pass it directly into the many-plies, to circulate between its leaves, before getting into the fourth stomach.

40. The object in view in the whole of this apparatus, is the detention of the vegetable food, and the exposure of it to a large surface. The calf passes its animal food, the milk, directly to the fourth stomach. We can note a similar object constantly kept in view in the comparative lengths of the intestines in different tribes. Thus, the ram has these twenty-seven times the length of its body, the ox twenty-two times, man five and a half times, the lion three times, and the shark little more than three-fourths of its length.

41. The stomach may be regarded as a kind of centre, with which every part of the animal economy sympathizes. It is well known that a violent blow in this region has frequently proved instantly fatal; a sudden draught of cold water, when the body is warm, sometimes has the same effect. Professor Christison mentions, that when he injected a poison, called oxalic acid, into the stomach of a dog, death took place instantaneously, and before it could

82. How do the ruminant animals differ from man in respect to the stomach?
83. Describe that of the sheep.
84. Wherein do the intestines of animals differ?
85. What illustrates the vital importance of the stomach?

possibly have been absorbed into the system. It is from this extensive sympathy that the feelings of hunger and thirst must, for the most part, be regarded as indications merely of the general state of the body. Grief and care, overtasking the brain, by long-continued study, indolent inactivity, oppressive labour, every act or habit, in fine, that has a tendency to destroy health, also impairs our appetite for food. The stomach is, in general, a faithful monitor, serving to warn us when we are violating those laws which the Creator has prescribed as necessary to preserve in perfection the animal frame.

42. It can easily be understood how important is the proper performance of the digestive functions. The circumstances most essential in securing this are—1st, and above all, an originally sound constitution. Without this, some part of the animal machinery will continually be found going wrong, and, perhaps, more than any other, the digestive organs. 2d, Temperate habits, regular exercise, and a cheerful mind. 3d, A proper quality and quantity of food. The lower orders in this country suffer from the quality of their food, which is often very indigestible; the better ranks suffer more from the quantity taken. In both, the bad effects are most marked when combined with sedentary or intemperate habits.

43. The alimentary canal is liable to many diseases, and among the most common is inflammation, which affects it variously as its different coats are attacked. When the outer or serous coat is attacked, pain upon pressure is generally intense; when the muscular coat is attacked there is generally violent twisting pain; but its principal effects are shown in impediments to the passage of the excrement, constituting what is commonly called iliac passion. When the mucous or inner coat is inflamed, it quickly becomes softened or ulcerated (eaten away), and vomiting, purging, or both, are its effects. In the cholera of this country, the whole extent of this coat is frequently

86. Does the mind affect the stomach?
87. What reflection is suggested?
88. How may we promote healthy digestion?
89. What of the diseases of the intestines?

affected; in dysentery it is principally the lower portion of it which suffers.

44. The mesenteric glands (Fig. 13, *d d*) occasionally become diseased in childhood, and prevent the chyle from properly entering the system. Children thus affected present the singular spectacle of eating voraciously, at the same time that they are becoming more and more emaciated.

The teacher will increase the interest of this section, by exhibiting the arrangement of the teeth and jaws in the dog, cat, sheep, hare, haddock, &c. A horizontal section of a horse's molar tooth polished shows the enamel going into the interior. In preparing the skulls or bones of any animal, all that is required is to allow them to macerate in water till the flesh rots off, and then clean them.

To show the parts concerned in deglutition, take a sheep's head, being careful that the butcher has left the upper part of the windpipe uninjured. Saw through the whole of the skull and the brain perpendicularly downwards, half an inch anterior to the horns; forcibly separate these two portions of the skull, and detach the posterior from the articulations of the lower jaw and the soft parts with a scalpel, the finger being pushed upwards into the gullet as a guide to prevent the pharynx being injured. This being done, the back part of the pharynx and gullet may be laid open, and the parts seen as in Fig. 11. The lowest portion of the gullet should not be cut, and a cork may be placed in it to show its course. When this has been examined properly, the tongue may be detached from the lower jaw by cutting close to the latter, and its connections with the epiglottis, &c., seen. This preparation is easily made, and at once gives a perfect conception of these complicated parts even to children.

To see the intestinal canal, &c., the abdomen of a hare or rabbit may be opened. The mesentery, liver, stomach, small and large intestines, &c., may be seen; but the latter are considerably different from the human. The sheep's stomachs, as in Fig. 14, are easily got and examined. They should be cut open as shown, and merely well washed with cold water. Note in them the channel formed from the gullet, and the vicinity of the latter to all the stomachs, the great increase of surface produced by their internal structure, foldings, &c., and the thick pylorus at the extremity of the fourth stomach.

In the fowl, the gizzard is a curious object, with its glandular stomach above, and the intestines going off from it on one side.

A short intestinal canal is well seen in the haddock, &c.

As comparatively accessible books in which other appropriate figures to illustrate this section are to be found, we may mention Dr. Roget's Bridgewater Treatise and Dr. Smith's Philosophy of Health.

[The directions given in this note are more curious than useful for practical purposes, especially in the schools.]

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90. The effect of early disease in the mesentery.

SECTION III.

THE CIRCULATION.

45. In the preceding section we have traced the progress of the food during its mastication, deglutition, and digestion. We have seen it converted into chyle, taken up by the lacteals, and, through the thoracic duct, poured into the veins of the neck. Here we lose sight of it as chyle. In the new system of vessels into which it has entered, it undergoes alterations, all of which are not yet perfectly understood, but which completely assimilate it to the nature of the blood, of which it hereafter forms a part. We are thus brought to consider a second important department of our science, the circulation of the blood; but first it is necessary to inquire into the nature of the blood itself.

46. With the appearance of *blood*, as it occurs in the higher classes of animals, every one is familiar. When drawn from one of the vessels which immediately receive it from the heart, and which are called arteries, it is of a bright scarlet colour; but when taken, as it usually is in the common operation of bleeding, from a vein, it is much darker, being of the shade called by painters Modena red. When first drawn from the vessel, it is a somewhat glutinous and apparently homogeneous fluid, but, after standing for a short time, it separates into two parts, one a watery part, called the *serum*, the other a more solid part, called the clot, or *crassamentum*. The serum is chiefly composed of water, with a considerable quantity of the same substance as the white of the egg (*albumen*) dissolved in it; so that, if it is exposed to a boiling heat, this coagulates and makes the whole solid. The clot, again, likewise consists of two principal substances, one of which gives it the red colour, and, by repeated washings, can easily be separated from the other, which is a white,

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91. Enumerate the successive changes upon the food.

92. Describe the blood, its difference of colour, and the parts into which it separates.

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THE CIRCULATION.

45. In the preceding section we have traced the progress of the food during its mastication, deglutition, and digestion. We have seen it converted into chyle, taken up by the lacteals, and, through the thoracic duct, poured into the veins of the neck. Here we lose sight of it as chyle. In the new system of vessels into which it has entered, it undergoes alterations, all of which are not yet perfectly understood, but which completely assimilate it to the nature of the blood, of which it hereafter forms a part. We are thus brought to consider a second important department of our science, the circulation of the blood; but first it is necessary to inquire into the nature of the blood itself.

46. With the appearance of *blood*, as it occurs in the higher classes of animals, every one is familiar. When drawn from one of the vessels which immediately receive it from the heart, and which are called arteries, it is of a bright scarlet colour; but when taken, as it usually is in the common operation of bleeding, from a vein, it is much darker, being of the shade called by painters Modena red. When first drawn from the vessel, it is a somewhat glutinous and apparently homogeneous fluid, but, after standing for a short time, it separates into two parts, one a watery part, called the *serum*, the other a more solid part, called the clot, or *crassamentum*. The serum is chiefly composed of water, with a considerable quantity of the same substance as the white of the egg (*albumen*) dissolved in it; so that, if it is exposed to a boiling heat, this coagulates and makes the whole solid. The clot, again, likewise consists of two principal substances, one of which gives it the red colour, and, by repeated washings, can easily be separated from the other, which is a white,

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91. Enumerate the successive changes upon the food.

92. Describe the blood, its difference of colour, and the parts into which it separates.

tough, fibrous matter. It is known by the name of *fibrin*, and is said to be nearly identical in composition with the part that gives contractility to the muscles.*

47. Although the blood in all animals appears to be of essentially the same nature, separating when out of their bodies into a solid and a serous part, yet, in a large proportion of the lower classes, it has not the same florid appearance which it assumes in most of the Vertebrata. Thus, in insects, this fluid is nearly transparent, while in the caterpillar it has a greenish hue. In fishes, again, it is transparent in the bulk of the body, but it has a red colour in the gills, heart, and liver; and even in the human body, some textures, as the transparent parts of the eye, circulate only a colourless fluid. In certain diseased states of the system, indeed, nearly the whole blood becomes colourless. A man died in Leith about eighteen years ago, who for more than eight months before his death looked exactly like a person recovering from a fainting fit, and his body, after death, was found almost destitute of red blood. An alarming form of the same disease appeared in 1803 among the coal-miners at Anzain in France. Their faces assumed the appearance of yellowish wax, and not a trace of blood-vessels could be seen even on the inner parts of the eyelids or mouth.

48. When the blood is examined with a microscope, its florid colour is perceived to arise from numberless extremely minute red globules supended in the watery serum. These have, in every species where they exist, a determinate size and form, being in man of a circular flattened shape, and from the 3000th to the 5000th part

* The following, made by M. Le Canu, is the most recent analysis of the composition of the human blood;—Water, 786·500; albumen, 69·415; fibrin, 3·565; colouring matter, 119·626; crystallizable fatty matter, 4·300; oily matter, 2·270; extractive matter, soluble in alcohol and water, 1·920; albumen combined with soda, 2·010; chloruret of sodium and potassium, alkaline phosphate, sulphate and subcarbonate, 7·304; subcarbonate of lime and magnesia, phosphates of lime, magnesia and iron, peroxide of iron, 1·414; loss, 2·586. Total, 1000.

93. The different colours of the blood in other animals.
94. Changes in disease.
95. To what is the colour of the blood ascribed?

of an inch in diameter. In birds, reptiles, and fishes, they get progressively larger, assuming at the same time an elliptical form, and in the skate they are larger than in any other animal hitherto examined. Their number corresponds very constantly to the temperature of the animal, and hence the two divisions of warm and cold-blooded. In birds the red globules constitute in general about fourteen or fifteen per cent. by weight of the whole mass, in man twelve or thirteen per cent., and both of these are warm-blooded animals. The red globules in fishes (which are cold-blooded, or only slightly warmer than the water in which they live) amount to about five or six per cent. It is also stated that these globules are in general more numerous in the blood of men than in that of females, and in persons of a sanguine than in those of a lymphatic temperament.*

49. One of the most singular properties of blood, is its power of coagulating. It has been supposed that the globules of blood are really vesicles or bags, the outer portion of which is composed of red colouring matter, while the centre consists of fibrin; and that, during coagulation, the vesicle is burst, and the particles of fibrin adhere to each other. But it has been more recently shown, by the experiments of Babington and Müller, that the fibrin is not contained in the red globules, but in the fluid part of the blood in which they float. When inflammation exists, the separation of the two parts is most complete, the yellow or upper buffy layer being the fibrin. Much beautiful design, as Dr. Prout remarks, is probably concealed under this arrangement. One object of it is evident. If the blood did not coagulate, the existence of animals would be most precarious, as, on the slightest injury, they would be liable to bleed to death. Nor is the danger apprehended imaginary, for an unnatural state of fluidity in the blood has frequently, when the most trifling wounds were received, been attended with alarming bleeding, or even

* These terms will be explained immediately.

96. How do these differ in animals?
97. What of the coagulation of blood?

with death. A family in Oldenburg lost four children from this cause, and a daughter of the same family had three children who also died of this disease.

50. There must, therefore, evidently be a cause for the fluidity of the blood within the body, and many experiments render it highly probable that this depends, to a certain extent at least, upon the vitality of the veins and arteries circulating it. Even the vitality of the blood itself is made more than probable by the experiments of Mr. John Hunter. Like the egg, it can within certain limits resist the influence of various agents, such as heat and cold, while it retains life, but yields to them when it dies. An electric shock passed through it, instantly extinguishes its vitality, and this is the reason why the blood in persons struck dead by lightning is always fluid.

51. While Physiologists had yet but inaccurate ideas of the uses and structure of different organs, great benefits it was thought might follow from transfusing a healthy animal's blood into a diseased person's body, and some dangerous and even fatal experiments of this kind were performed in France, until the practice was interdicted by law. Of late years the practice has been successfully revived, in cases where great loss of blood has happened, and its previous failure has been shown to have arisen from transfusing the blood of one species into the body of another, in which the globules are of a different size or shape. The blood of a sheep, for example, transfused into a cat or rabbit, causes death in a short time; and instantaneous death follows the transfusion of blood with circular globules into an animal which has these elliptical.

52. If other substances are mingled with the blood, equally serious effects follow. Farriers produce instantaneous death in horses by blowing air into their veins; and a person in Paris, a few years ago, who was having an operation performed in which a large vein in the neck had to be cut, from the entrance of air fell over and expired

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98. What of the fluidity of the blood?
99. What of the transfusion of the blood?
100. What of air in the vessels?

Many other cases have since been published, in which it is probable death occurred from the same cause.

53. Having made these observations regarding the blood, we must now explain the means employed for its circulation; and in doing so, we shall first describe this as it takes place in man and in the other Mammalia; for though their circulating system is really the most complex, a knowledge of it forms a key to all the modifications which it sustains in the other classes.

54. The course of the circulation of the blood was unknown until the reign of James I., when it was discovered by Dr. Harvey. The ancients knew of the existence of the veins and arteries, but thought that the blood was moved backwards and forwards in the veins, and that the arteries were filled with air. The name of the latter, indeed, is derived from *arteria*, or air-tube. Harvey publicly taught his new doctrines as early as 1616; but, with a caution worthy of one whose fame was to be coeval with our race, spent no less than twenty-six years in amassing materials for his immortal work on the Circulation. The reception it met with, when published, is instructive. Derided by his own profession as a quack, he was looked upon by the vulgar as crackbrained; and in a letter written to a friend at this period, he complains that his practice had suffered seriously since the publication of his book. To the honour of mankind, however, it must be said that he lived long enough to see his system taught in every university in the world.

55. The circulating system in the Mammalia may be said to consist of four principal parts—first, the heart, which is the centre of the whole; second, the arteries, which receive the blood from the heart; third, the veins, which return the blood to the heart; and, fourth, the capillary (hair-like) vessels, which unite the termination of the arteries with the commencement of the veins.

56. Every one knows the appearance of the heart—an ox's or a sheep's, for example. When cut up, it is found

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101. What theory of the circulation prevailed until the time of Harvey?
102. Name the four parts of the circulating system in man.

to consist of four cavities, two on the right side that communicate with each other, and two similar ones on the left side which also communicate with each other, but not directly with those opposite. The diagram, figure 15, affords an exact representation of the human heart, with the circulation of the blood to and from the lungs on both sides.

57. To make the course pursued by the blood more plain, we take asunder the two sides or chambers of the heart, and represent them as separate from, and opposite to, each other, as seen in Fig. 16.

58. In this *ideal* plan of the circulation in the Mammalia, the arteries and veins are *supposed* to be thrown into continuous chains, with the capillaries as their connecting links. In describing this plan, we shall commence with the veins, which have been coloured blue, to indicate that they convey impure blood. It will be seen that they

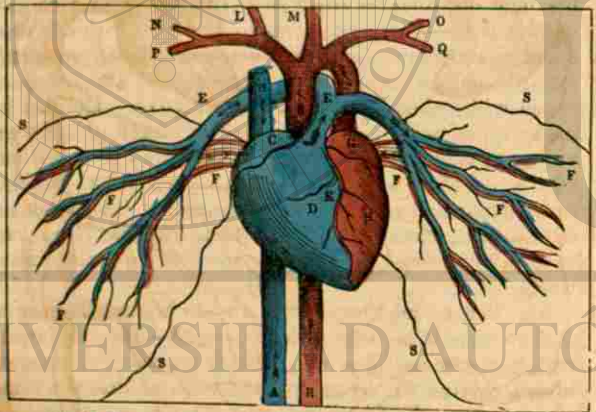

Fig. 15. Representation of the Human Heart, Vessels, and Lungs.

A Vena cava ascendens.
B Vena cava descendens.
C Right Auricle.
D Right Ventricle.
E Pulmonary artery.
F Pulmonary veins.
G Left auricle.
H Left ventricle.
I Aorta ascendens and branches.
K Coronary arteries.
LM Carotid arteries.
NO Vertebral arteries.
PQ Subclavian arteries.
R Aorta descendens.
SS Outline of Lungs.

103. What are the four cavities of the heart called?
104. Explain the coloured diagram.

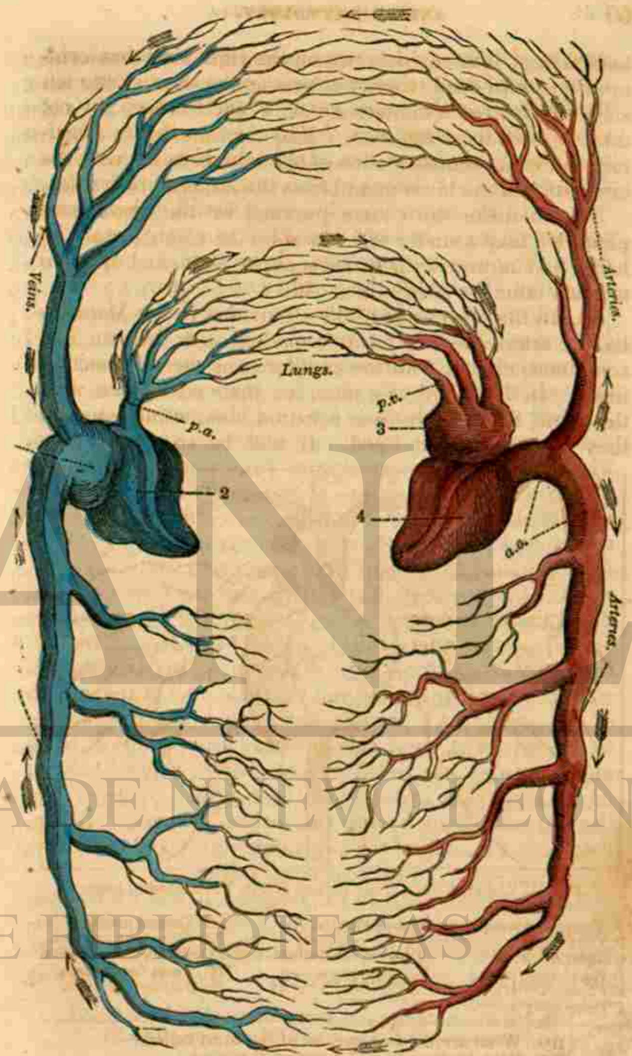

Fig. 16. Ideal plan of the Circulation of the Mammalia.

gradually unite, until those coming from above and those from below form two large vessels (*venæ cavæ*), that empty themselves into the upper cavity of the heart on the right side, called the *right auricle* (1). From the contraction or drawing together of this auricle, the blood easily passes downwards into the next cavity, called the *right ventricle* (2); and this, which is still more powerful, also in its turn contracting upon the blood, sends it through the vessel (*p a*) called the *pulmonary artery*. It is plain, however, that, if nothing hindered it, the blood could as easily go back to the right auricle, as forwards into the pulmonary artery; but this is effectually prevented by a valve that is placed between the right auricle and the right ventricle, and which allows the blood to enter, but prevents it going back. Another valve, which acts in a similar manner, is placed at the mouth of the pulmonary artery, so that the blood, by the successive contractions of the ventricle, is forced to go forward into the lungs. Here, as will afterwards be explained, it becomes purified, as is shown by its red colour, and is sent by the *pulmonary veins* (*p v*) to the *left auricle* of the heart (3), to pass, as on the other side, into the *left ventricle* (4). This last is the most powerful of all the parts described, as it is required to propel the blood into the artery called the *aorta* (*a o*), and from it into the whole of the body. Valves are placed on the left side, between the auricle and ventricle, and at the mouth of the aorta, which have a similar action and appearance to those on the right side. Those between the auricles and ventricles are called cuspid, that is, pointed valves; on the right side, from having three points, tricuspid; on the left side, from having two points, bicuspid. Again, those at the mouths of the pulmonary artery and aorta are, from their shape, called semilunar valves.

59. The blue colour in the diagram, it will be noticed, at once gives an idea of the parts of the body in which impure or venous blood is circulated (the veins, right side of the heart, and pulmonary artery). The red colour also

105. Name the arteries and veins connected with the heart?
106. Where are the valves, and what are they called?
107. What vessels connect it with the lungs?

indicates in what part the blood becomes purified (the lungs), and where it is circulated as arterial or pure blood (the pulmonary veins, left side of the heart, and arteries). It is in the capillaries between the arteries and veins (which are too minute to be represented in the diagram, but which pervade every point in our bodies) that the blood parts with its vivifying qualities. The communication of these qualities to the different structures, may be said, indeed, to constitute the great object of the circulation. The arrows in the figure also show the course pursued by the blood. Figure 21 shows the situation of the heart in the chest, with the aorta (*h*) and its branches going off from it. *a* is the two ventricles united. *k* and *s*, the two auricles. *l l*, the carotid arteries going to the head. *m* is the superior vena cava (which empties itself into the right auricle), in which the jugular veins (*n n*) from the brain, and the subclavian veins from the arms (*o o*), are seen to terminate.

60. The course of the circulation, as shown in Fig. 15, will now be easily understood. The two venæ cavæ A B empty themselves into the right auricle C. From this the blood passes into the right ventricle D, which sends it into the pulmonary artery E, and this immediately divides in the lung SS into innumerable branches, only a few of which are represented in the diagram. In the lungs, as already mentioned, the blood is purified, and the pulmonary veins FF are therefore represented as bringing back to the heart red or arterial blood. The pulmonary veins from both sides pour their supplies of blood into the left auricle G, from which again it passes into the left ventricle H, and is by the latter sent to all parts of the body through the aorta I and its branches, to be again conveyed by the veins to the right side of the heart. R is the continuation of the aorta, which carries the blood to the lower parts of the body. By attending to the directions indicated by the arrows, the course of the circulation in this and the other figures will be made very plain.

108. What of the blue and red colours of the blood?
109. Where is the blood purified, and where is it deprived of its vivifying properties?

61. From the description given, it must be plain that the office filled by the heart, with its accurately-working valves, is essentially that of a forcing-pump. And with what inimitable precision and regularity does it perform this all-important duty! Unweariedly during the whole term of a long life it sends out daily its 100,000 waves of healthful fluid to refresh and renovate every corner of the system; and small as each wave may be individually, the aggregate amount is enormous. Thirteen thousand pounds of blood pass out of the left ventricle of the heart of an ordinary man every twenty-four hours. But the aorta of a man is not an inch in diameter, whereas the aorta of a whale, the skeleton of which is exhibited in Edinburgh, was three feet two inches in circumference. Well, therefore, might Dr. Paley say, that the circulation is a serious affair in such an animal. "The aorta of a whale," says he, "is larger in the bore than the main pipe of the water-works at London Bridge; and the water roaring in its passage through that pipe, is inferior in impetus and velocity to the blood gushing through the whale's heart."

62. But if we are astonished in reflecting on what must take place in the aorta of the whale, our admiration will be not less excited on examining the circulation even in the web of a frog's foot. When this is brought under a moderately powerful microscope, we can perceive with ease, through the transparent coats of the tiny vessels, the red globules of the blood—in some singly, with long intervals between—in others, two abreast—and, in others still, numbers crowded together—pursuing their beautiful course, like the trains of spectral figures that pass before us in our dreams—now moving onwards with the most steady regularity, and again hurried forward by the struggles of the little animal. This sight, an excellent writer well observes, "is one which no man who has once seen can ever forget; and he who has not seen it, has not beheld one of the most

110. Describe the course of the circulation.
111. What reflection does the subject suggest?
112. How wonderful the quantity, and force of the heart's action?
113. What of the whale's heart, and of the frog's foot?

curious, and wonderful, and beautiful objects which animated nature presents."

63. Like most of the organs of organic life, the heart, in its usual state, gives us but slight indications of sensibility. Harvey met with an extraordinary opportunity of showing this. A young nobleman, from disease, had the heart exposed, so that it could even be handled while beating; and Harvey, to his astonishment, found that, unless his fingers came in contact with the outer skin, the young man was altogether unconscious of the heart being touched. Though nearly destitute of the sensations of touch, however, the heart is instantly affected by every powerful bodily excitement, or strong mental emotion. Upon the first of these depends the use physicians make of the pulse (which is just the heart's beat transmitted through the arteries) in judging of the different bodily ailments; while the power of emotions over the heart has furnished the poetry of all languages with some of its strongest images. The capillaries also share in the influence of emotions, of which we have a familiar example in blushing.

64. The greater or less vigour with which the blood is circulated through the system, gives rise to important effects. We see this particularly in two forms of constitution. In the one, the circulation is very vigorous; all the functions are performed with energy; and the diseases, in general, are of an acute character. When the complexion is fair, this constitutes what has been called the sanguine temperament—when dark, the choleric. In the other variety, the circulation, and all the functions connected with it, are languidly performed; the surface is easily chilled, and the diseases have frequently a low insidious character. When the complexion is fair, this has been called the phlegmatic temperament, and the melancholic when the complexion is dark. With a feeble circulation, the general health never can be good; and hence we find the action of the heart weak in most delicate persons.

114. What of the sensibility of the heart?
115. How is the heart shown to sympathize with body and mind?
116. What differences in the circulation?
117. What temperaments, and how marked?

65. The arteries, like the intestines, are composed of three coats, and the middle one is generally considered to be muscular, in order to assist the contractions of the heart; but its muscularity is by no means so marked as is the muscularity of the intestinal canal. These coats possess, also, different degrees of distensibility, the inner one being least so. This gives rise to the remarkable circumstance, that when, as in those horrid accidents that are sometimes caused by machinery, a limb is torn off, frequently not a spoonful of blood will be lost. The reason is, that the inner coat, which is ruptured first, curls up, and, assisted by the outer coat, forms a plug in the blood-vessels. These coats are sometimes distended more gradually by the continued impulse of the heart, constituting the disease called aneurism. The sac thus formed, if on the largest vessels, occasionally attains the size of a child's head, and produces instantaneous death when it ultimately bursts.

66. The part of the circulating system most liable to disease is the valves, and especially those of the left side of the heart. Ossification, or the deposition of bone in their substance, is what most commonly affects them. As might be anticipated, the blood regurgitates and stagnates, and great distress in breathing, dropsy, &c., are the consequences. The only other valves in the circulating system are in the veins, and they seldom become diseased.

67. When the apparatus employed in the circulating system of man is understood, it will be easy, from a mere inspection of the coloured figures, to comprehend its modifications in other animals. Birds have a circulation similar to that of the Mammalia. An *ideal* plan of the circulation in reptiles is seen in Fig 17. They have a right and a left auricle (*a b*), but only one ventricle (*c*). Commencing, as we did before, with the veins, we find that the whole venous blood is emptied, as in man, into the right auricle (*a*), and, from this, is sent into the ventricle

118. What of the arteries?
119. The part of the heart most liable to disease.
120. The circulation of reptiles.

(*c*). From the ventricle, the blood is sent into a large vessel (*d*), and is then distributed as follows: First a small portion goes to the lungs by the vessel *e*, to be purified, and then brought to the left auricle (*b*), and from this to

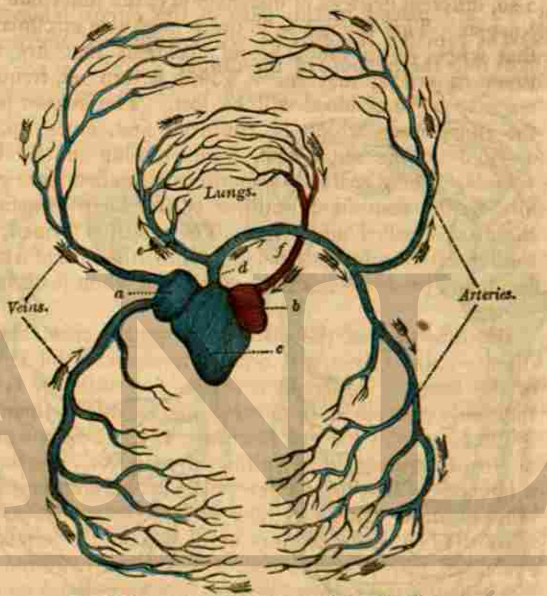

Fig. 17. Ideal Plan of the Circulation in Reptiles.

pass again into the ventricle, where it mixes with the impure blood coming from the right auricle; second, the rest of the blood goes to the upper and lower parts of the body by the arteries. The blue colour shows where the venous blood circulates (in the veins and right auricle). The red colour shows where it is arterialized (in the lungs), and where it circulates as red blood (in the pulmonary veins (*f*) and left auricle (*b*). The purple colour shows in what

121. Describe this coloured diagram.

parts the mixed pure and impure blood circulates (in the ventricle (*c*), pulmonary artery (*e*), and all the other arteries).*

68. In fishes, as will be seen in Fig. 18, there are only two cavities in the heart, an auricle (*a*) and a ventricle (*b*), which are placed in the part of the circuit where the blood is venous; the gills, as will be explained afterwards, answering the purpose of the lungs.

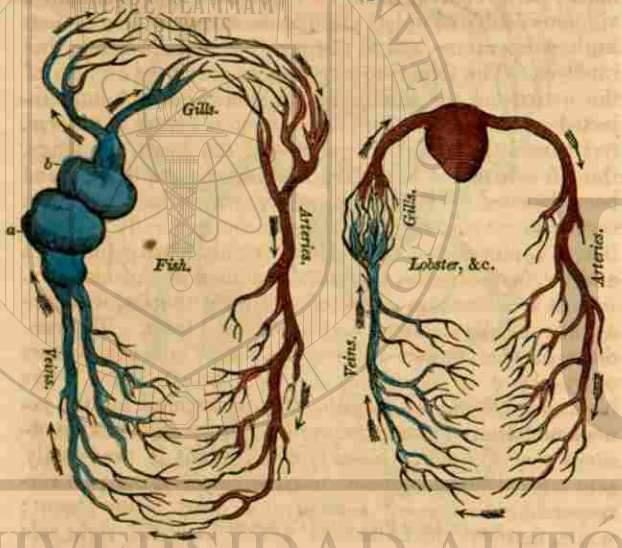

Fig. 18. Fig. 19.

69. Among the Crustacea, again (as the crab, lobster, craw-fish, &c.), there is only one cavity, like a fleshy ven-

* The crocodile, one of the highest species of reptiles, has the ventricle divided like the Mammalia, and the venous is mingled with the arterial blood only in the hinder parts of the body, by a vessel which comes from the pulmonary artery, and joins the aorta low in the back. From this cause, pure arterial blood circulates in its brain and anterior parts, while mixed venous and arterial blood circulates posteriorly.

122. What peculiarity in fishes?
123. Explain the diagrams.

tricle, which, it will be seen in Fig. 19, is placed in the arterial part of the circuit.* In the orders below this, the heart is rudimentary, or wanting; and its duties, much simplified, are performed in many by a large vessel running along the back.

70. Looking at the whole figures in these diagrams of the circulation, we see, first, in man and the other Mammalia, parts equivalent to two hearts, which maintain a vigorous double complete circulation, corresponding to their high temperature, and to the activity of their habits and intellect. The following experiment may give an idea of the activity of the circulation in this class:—A fluid injected into one of the jugular veins in the neck of a horse, has passed through the right side of the heart, the lungs, the left side of the heart, the arteries, the capillaries, and been detected in the vein of the leg, within half a minute; secondly, we see, corresponding to the generally sluggish life of reptiles, that their blood is only partly purified; and we may observe, that this condition of the blood exists as a disease, in some of our own species, who are always, in like manner, very feeble and inert. The condition alluded to (called the blue disease) arises from parts of the heart, or its vessels, that are naturally open before birth, not closing afterwards, and hence allowing the venous and arterial blood to mingle; thirdly, in fishes we observe that the whole blood is purified, but is necessarily sent with decreased force into their bodies, the part corresponding to the left side of our heart being absent; while, fourthly, the Crustacea, which have the right side absent, present us with the most unfavourable modification of the heart's position. Before the impulse of the heart can reach the gills, it must evidently propel the blood

* The Sepia has the heart likewise placed in the arterial part of the circuit, and the two veins that carry the blood to the gills also swell out into something like the rudiments of two other hearts in the venous part of the circuit. The two vessels connected with the auricle and ventricle of the fish, as may be observed, also swell out into what are called sinuses.

124. Describe the double circulation in man and the mammalia.
125. Illustrate the activity of the circulation in man and the horse, while it is sluggish in some other animals.

through the arteries, capillaries, and veins; and the blood must, therefore, feebly enter the minute vessels in the gills, where purification takes place.

The parts of the circulating system most difficult to be understood, are the valves of the heart and their action. Both these can be beautifully shown in a cow's heart, the vessels of which have been cut high up, and as little injured as possible. The hard suet being cleared from the base of the heart, to show the bicuspid valve between the left auricle and ventricle, pass the finger into the large opening of the aorta (which is the vessel butchers often hang the heart by) nearest the heart, when will be felt the semilunar valves at the mouth of the left ventricle. These must be broken down by cautiously introducing a scalpel, or penknife, and cutting and then forcibly rupturing them with the finger. Having done this, close all the openings on the sides of the aorta, by tying them, or transfixing them with a needle, and twisting thread round it, or putting a small cork in the largest, fastening with needles, and twisting thread around them, &c. Now pour water gently into the aorta, and notice where it escapes. This will be by the left auricle, which is to be cautiously removed, (but not cut quite to its base,) until the valves are exposed. If water is now poured quickly into the aorta, the bicuspid valve will be seen to be lifted up, and to prevent its escape; or, what is better, the air may be made to take the place of the water, by drawing in the breath and blowing forcibly, in quick succession, through the aorta. The action of the valve during life may thus be shown with tolerable accuracy.

When this has been examined, the heart should be cut through transversely, two or three inches above its apex, to show the greater thickness of the left than the right ventricle. The left ventricle and aorta may then be cut up to show their internal surface—the fleshy columns and tendinous cords, which assist the heart in contracting, the appearance of the bicuspid and semilunar valves, the grooves leading to the branches from the aorta, &c.

The actions of the semilunar valves may now be shown by cautiously cutting away the right ventricle, till the valves at the mouth of the pulmonary artery are exposed. Take a pig's bladder, and cut about two inches off each extremity. Sew the narrower end round the inner surface of the pulmonary artery; pour a jugful of water quickly into the bladder, and the action of the valves, in preventing its return, will be seen.

By mixing Paris plaster (which may be got from any plasterer) bulk for bulk with the water, casts of the pulmonary valves, of the left ventricle, &c., may be made, and cut out when dry. To take a cast of the right ventricle, the pulmonary valves must be broken down, as above. These make very instructive preparations, when the valves, &c., are distinguished by being coloured.

Attention should also be directed to the great difference in muscularity between the auricles and ventricles, and to the sounds of the heart as they can be heard by applying the ear to the left side of the chest of a thin person. The first dull sound is supposed to be produced principally by the contraction of the ventricles; the succeeding sharp sound by the falling back of the blood on the semilunar valves.

In disease, these sounds become louder and much altered—in some cases resembling the blowing of bellows, and in others, the rasping of a file, &c. The contraction of the heart is called its systolé, the time it rests its diastolé.

To show the fibrin of the blood, get some from the butcher, (who extracts it by turning his fingers in the blood while coagulating), and wash it till it is pure white. The coagulability of the serum (which can easily be got from any surgeon) should be shown by heating it in a Florence flask.

As mentioned in the text, the microscope shows the circulation in a frog's foot.

Other figures to illustrate this section may be found in "Animal Physiology" in the Library of Useful Knowledge, pages 69, 70, 71, 73, 74; in Dr. Roget's Bridgewater Treatise; in Dr. Smith's Philosophy of Health; in Bell's Anatomy, &c.

[The foregoing explorations are not recommended for young people.]

SECTION IV.

RESPIRATION.

71. We have seen, in the preceding section, the course which the blood pursues. We have now to consider the changes it undergoes in that course. It will be recollected that the left side of the heart sends the blood into the general system: this is called the *systemic circulation.* The right side of the heart sends it into the lungs, and this has received the name of the *pulmonic circulation.* But if the blood that goes to the lungs were returned in the same state as it is sent, death would be the consequence, for venous blood is a poison to the body; and this is the reason why an animal dies when the air is prevented from getting into its windpipe, by hanging or drowning. Bichat showed this very decisively. He connected, by a tube, the jugular vein of one dog with the carotid artery (which sends the blood to the brain) of another, and allowed the venous blood to flow into it. The immediate effect of this was, that the dog in whose brain the venous blood was made to circulate, became com.

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126. What two circulations are spoken of?
127. Bichat's experiment.

through the arteries, capillaries, and veins; and the blood must, therefore, feebly enter the minute vessels in the gills, where purification takes place.

The parts of the circulating system most difficult to be understood, are the valves of the heart and their action. Both these can be beautifully shown in a cow's heart, the vessels of which have been cut high up, and as little injured as possible. The hard suet being cleared from the base of the heart, to show the bicuspid valve between the left auricle and ventricle, pass the finger into the large opening of the aorta (which is the vessel butchers often hang the heart by) nearest the heart, when will be felt the semilunar valves at the mouth of the left ventricle. These must be broken down by cautiously introducing a scalpel, or penknife, and cutting and then forcibly rupturing them with the finger. Having done this, close all the openings on the sides of the aorta, by tying them, or transfixing them with a needle, and twisting thread round it, or putting a small cork in the largest, fastening with needles, and twisting thread around them, &c. Now pour water gently into the aorta, and notice where it escapes. This will be by the left auricle, which is to be cautiously removed, (but not cut quite to its base,) until the valves are exposed. If water is now poured quickly into the aorta, the bicuspid valve will be seen to be lifted up, and to prevent its escape; or, what is better, the air may be made to take the place of the water, by drawing in the breath and blowing forcibly, in quick succession, through the aorta. The action of the valve during life may thus be shown with tolerable accuracy.

When this has been examined, the heart should be cut through transversely, two or three inches above its apex, to show the greater thickness of the left than the right ventricle. The left ventricle and aorta may then be cut up to show their internal surface—the fleshy columns and tendinous cords, which assist the heart in contracting, the appearance of the bicuspid and semilunar valves, the grooves leading to the branches from the aorta, &c.

The actions of the semilunar valves may now be shown by cautiously cutting away the right ventricle, till the valves at the mouth of the pulmonary artery are exposed. Take a pig's bladder, and cut about two inches off each extremity. Sew the narrower end round the inner surface of the pulmonary artery; pour a jugful of water quickly into the bladder, and the action of the valves, in preventing its return, will be seen.

By mixing Paris plaster (which may be got from any plasterer) bulk for bulk with the water, casts of the pulmonary valves, of the left ventricle, &c., may be made, and cut out when dry. To take a cast of the right ventricle, the pulmonary valves must be broken down, as above. These make very instructive preparations, when the valves, &c., are distinguished by being coloured.

Attention should also be directed to the great difference in muscularity between the auricles and ventricles, and to the sounds of the heart as they can be heard by applying the ear to the left side of the chest of a thin person. The first dull sound is supposed to be produced principally by the contraction of the ventricles; the succeeding sharp sound by the falling back of the blood on the semilunar valves.

In disease, these sounds become louder and much altered—in some cases resembling the blowing of bellows, and in others, the rasping of a file, &c. The contraction of the heart is called its systolé, the time it rests its diastolé.

To show the fibrin of the blood, get some from the butcher, (who extracts it by turning his fingers in the blood while coagulating), and wash it till it is pure white. The coagulability of the serum (which can easily be got from any surgeon) should be shown by heating it in a Florence flask.

As mentioned in the text, the microscope shows the circulation in a frog's foot.

Other figures to illustrate this section may be found in "Animal Physiology" in the Library of Useful Knowledge, pages 69, 70, 71, 73, 74; in Dr. Roget's Bridgewater Treatise; in Dr. Smith's Philosophy of Health; in Bell's Anatomy, &c.

[The foregoing explorations are not recommended for young people.]

SECTION IV.

RESPIRATION.

71. We have seen, in the preceding section, the course which the blood pursues. We have now to consider the changes it undergoes in that course. It will be recollected that the left side of the heart sends the blood into the general system: this is called the *systemic circulation.* The right side of the heart sends it into the lungs, and this has received the name of the *pulmonic circulation.* But if the blood that goes to the lungs were returned in the same state as it is sent, death would be the consequence, for venous blood is a poison to the body; and this is the reason why an animal dies when the air is prevented from getting into its windpipe, by hanging or drowning. Bichat showed this very decisively. He connected, by a tube, the jugular vein of one dog with the carotid artery (which sends the blood to the brain) of another, and allowed the venous blood to flow into it. The immediate effect of this was, that the dog in whose brain the venous blood was made to circulate, became com-

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126. What two circulations are spoken of?
127. Bichat's experiment.

pletely insensible, and would in a short time have died. On allowing the arterial blood, however, again to circulate in its brain, the dog was quickly restored.

72 What are the changes, then, that take place in the lungs, and how are these changes effected? These questions will be best answered by first knowing what the lungs are. The lungs (vulgarly called *lights*) are principally composed, 1st, of air-tubes (bronchi) of which the windpipe (trachea), is the commencement, and which divide and subdivide until they terminate, as has been supposed, in very minute bags or air-vesicles; and 2dly, of the pulmonary artery (Fig. 15, E, and Fig. 16, *p*, *a*), which branches out upon the sides of these air-tubes. Fig. 20 shows the windpipe, with the lungs entire on one side, and with the branches of the air-tubes dissected on the other. These tubes are said to terminate in vesicles, which vary in size from the 50th to the 10 th part of an inch in diameter. The lungs are also seen in Fig. 21, in their natural situation in the chest.

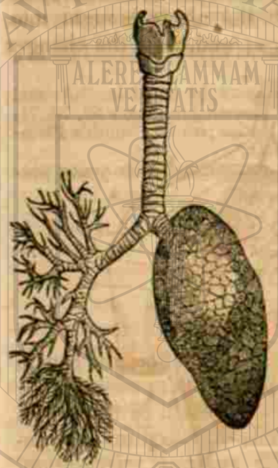

Fig. 20. Windpipe and Lungs.

73. If we tie up tightly in a bladder a quantity of venous or dark blood, we shall find, in a short time, that exposure to the air has changed the colour of the portion near the surface. The air has passed through the bladder, and has converted the venous into red or arterial blood. Exactly the same thing takes place in the lungs; for the air, in the air-vesicles, is separated from the blood in its vessels by a membrane not more than the thousandth

128. Describe the diagram.
129. The experiment with the bladder.
130. What changes its colour?

part of an inch in thickness. But we shall find, immediately, that it is not the blood alone that is altered in its qualities. The air undergoes alterations. The blood in the lungs also becomes fit for supporting life; the air becomes unfit for this purpose. We must, therefore, describe, 1st, the means by which the air is brought into, and then removed from, the lungs; and, 2dly, the changes

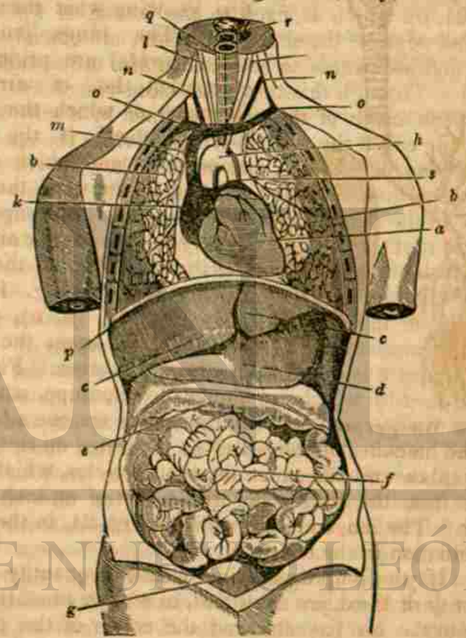

Fig. 21. Front view of the contents of the Chest and Belly.

a, the two ventricles of the heart. *k*, the right auricle. *s*, the left auricle. *h*, the aorta. *l l*, the carotid arteries. *n n*, the jugular veins; and *o o*, the subclavian veins, terminating in *m*, the superior vena cava. *b b*, the lungs. *q*, the windpipe. *r*, the gullet. *p*, the diaphragm. *c c*, the liver. *d*, the stomach. *e*, transverse arch of the colon, part of the large intestines. *f*, the small intestines. *g*, the bladder.

131. What change occurs in the blood and in the air?
132. Explain the diagram.

of composition that thence occur in the air and in the blood.

74. The lungs are contained in the chest or thorax (Fig. 7, *rxr*), a conical cavity formed by the breast-bone before, the back-bone behind, and the ribs above and on the sides. It is separated inferiorly from the abdomen or belly by a fleshy movable partition called the *diaphragm* (Fig. 21, *p*), which is fixed to the bottom of the breast-bone and edges of the short ribs before, and extends downwards and backwards to be attached also to the back-bone behind. Through this the gullet, blood-vessels, &c., pass. The whole inside of the chest is lined by a thin smooth membrane called the *pleura*, which divides the chest into a right and a left side, and which likewise covers the lungs; but these are, nevertheless, on the outside of the pleura, in the same way as the head is on the outside of a double nightcap. There is no opening to admit the air between the lungs and sides of the chest, but it gets easily by the windpipe into the air-tubes of the lungs.

75. From these explanations it will be easy to understand the mechanism of *respiration* (breathing). Drawing in a breath is called *inspiration*. We do this, 1st, by raising the ribs, which are provided with numerous muscles for this purpose between the ribs, and attached to the ribs and neck; and, 2dly, and at the same time, by depressing the diaphragm. Of the latter movement we become sensible, by placing the hand on the abdomen during inspiration, when we notice the ribs raised, and find the belly pushed outwards at the same moment by the descent of the diaphragm. It is, therefore, evident that the cavity of the chest must be considerably enlarged by inspiration. But the cavity of the chest cannot be enlarged without something filling it up; and as no air can get between the lungs and sides of the chest, if the windpipe remain open, the air necessarily rushes by it into the air-tubes and vesicles of the lungs, and blows them up as we might blow up a bladder. The muscles that acted during

133. Describe the bony structure of the chest.
134. What separates this from the abdomen?
135. What lines the chest, and covers the lungs?

inspiration having become relaxed, the expulsion of the air from the lungs is effected principally by the elasticity of the ribs, and by the contraction of the muscles of the belly pushing up the diaphragm. It is called *expiration*.

76. It must be manifest, from considering these arrangements, that the amount of blood and air brought together in the lungs must be very great. The whole extent of the air-tubes in man, taken collectively, has been calculated by Hales at about 20,000 square inches, and by Monro at twenty times the surface of the human body; the branches of the pulmonary artery, which ramify upon this surface, are so twined and interlaced that they have received the name, from anatomists, of *the wonderful network;* while the air received into and expelled from the lungs, and consequently brought into contact with its air-tubes and blood-vessels, cannot be less, in an ordinary man, than between 3000 and 4000 gallons daily.

77. Fresh supplies of air, then, that the blood may be purified, are the essential objects of a respiratory apparatus; and from the necessity of having some modification of such an apparatus, no animal whatever is exempted, although the supply of air required varies much. A frog or a lizard, for example, will live a considerable time in air which a bird has been forced to breathe till it has died, and insects will live for a long period even in the air that has ceased to support both the bird and the lizard. Fishes, again, whose gills, it was formerly mentioned, perform the same office as our lungs, can exist upon the small portion of air they extract from the water in which they swim. But, however small the quantity required, none can want it altogether; and if any of them be placed under the receiver of an air-pump, and the air be exhausted, they immediately become distressed, and die in a short time.

78. There is one remarkable circumstance that may be noted, when the motions of the heart, or intestines, and those of respiration, are contrasted. The motions of the

136. Define inspiration and expiration.
137. What of the extent of the air-tubes in the lungs?
138. What quantity of air?

former are entirely removed from the influence of the will, and usually do not excite in us any consciousness of their existence; while those of respiration are always accompanied by a sensation, if not also by an act of volition. Before air is drawn into the chest, we have always a peculiar sensation, reminding us that a fresh supply of this material is required. At first, this sensation is merely a gentle intimation; but, if neglected, it becomes so intolerably painful as to compel us to relieve it by breathing. When an individual becomes partly insensible, the sensation requires to be considerable before he attends to it; and accordingly we find, that, instead of breathing, as we ordinarily do, fifteen or twenty times in a minute, he will breathe only once in half a minute, a minute, or a minute and a half. When insensibility increases still further, this and all other feelings become extinct, and then he dies. Upon this principle an explanation has been given of sighing. When a person sighs, the mind has been intensely fixed on some object. The consequence is, Dr. Darwin supposes, that he forgets for a short time to breathe, until the sensation in the chest becomes so importunate as to oblige him to make a more than usually full inspiration to relieve it.

79. The mechanism of respiration is considerably modified in other classes. Whales (which breathe air) have parts that are thought to serve as reservoirs, both of venous and arterial blood; and this is conjectured to be the reason why they are able usually to remain under water twenty minutes, and sometimes upwards of an hour, without breathing. The lungs of birds, instead of being free in the chest, are fixed to its sides, and also have openings in them which allow the air to pass into air-cells that pervade almost every part of their bodies. As a proof of this, if the windpipe of an eagle be tied, and the largest bone of its wing (humerus) be broken, it can breathe through the

139. How do animals differ in their need of air?
140. What of voluntary breathing, its frequency, and cause of sighing?
141. What is peculiar in whales?
142. The wonderful peculiarity of birds illustrated.

broken bone instead of its windpipe. It is this arrangement that causes the respiration of birds to be called double, for the air acts on the blood, 1st, in passing through the lungs to the air-cells; 2dly, in passing out of these, and probably also while it remains in the air-cells. Hence, they consume more air than any other class of animals.

80. Reptiles can act but imperfectly on the air, from the cells of their lungs being very large, and, from this cause, of course diminishing the surface upon which the blood-vessels have to be distributed. The frog has no ribs, nor has it any diaphragm, the abdomen and chest forming but one cavity. As a substitute for these, the air is forced into the lungs by a species of deglutition. A frog perishes if its mouth is kept open, because, before this deglutition can be accomplished, the mouth must be closed.

81. The surface occupied by the gills of fishes is often very considerable. Those of the skate are said to have a surface nearly equal to that of the human body. The reason why air cannot usually be directly breathed by gills, is believed to be principally because they become collapsed and dry. The eel, the crab, and some other species, that breathe by gills, can, however, breathe in air for a considerable time.

82. The only other modification of the respiratory apparatus we shall refer to is that of insects. The veined appearance of the wings of the butterfly is produced by what are called tracheæ, that have openings on the surface (stigmata) for admitting the air, and extensive ramifications over the body. There are similar openings on the sides of the bee-worm and in other species. If these are closed, the animal immediately dies. In all the lowest classes of animals, and even as high as the class of reptiles, the skin is also an active respiratory organ.

83. What has been said may render intelligible the mechanism by which the air is introduced into the body. It will now be necessary to describe the changes that take place there. The atmospheric air, when it goes into the

143. Singularity in the frog, and fishes, and insects.
144. Composition of the air before and after respiration.

lungs, is composed of about four parts of a gas called nitrogen, and one part of another gas called oxygen.* But the air which comes out from the lungs is not the same in composition, for a considerable quantity of oxygen is found to have disappeared, and in its stead we find another gas, called carbonic acid, which is produced by the union of a portion of oxygen with the carbon which forms a large ingredient in the composition of the blood and of the body in general. Carbonic acid is a gas which is fatal to animal life, and it is therefore discharged from the lungs. If an animal is made to inhale it, insensibility and death follow in a very few minutes. We have already seen that the venous blood is a poison to the animal body, and it is probably this same carbon, or the carbonic acid, that makes it noxious. It appears that about 45,000 cubic inches of oxygen are consumed by an ordinary man in twenty-four hours, and that 40,000 inches of this gas go to form the carbonic acid produced during the same period, the remainder of the oxygen probably combining with other ingredients of the blood. Under different circumstances, however, the consumption of oxygen varies. It is considerably greater when the temperature is low than when it is high, and during digestion the consumption has been found one-half greater than when the stomach is empty. By violent exercise, when the stomach is empty, it has been found to be augmented to three times its usual quantity, and to four times its usual quantity when food has been taken after this.

84. When we thus see the great quantity of pure atmospheric air which a single individual requires to carry off the noxious parts of the venous blood, and to convert this into arterial blood, we can easily comprehend why such dreadful consequences should follow the breathing of a highly vitiated atmosphere. The most melancholy instance of this kind on record, is the well-known one that occurred in the Black Hole at Calcutta. In this dungeon,

* We omit mention of the small quantity of carbonic acid in the air.

145. What is discharged in expiration, and why?
146. Proportion of oxygen consumed in a day.

18 feet square, and having only two small windows on the same side to admit air, 146 men were immured. In six hours 96 of them had died from suffocation, after the most horrible sufferings; and in the morning, when the doors were opened, only 23 out of the whole number remained alive.

85. From the same cause we can understand how hurtful it must be continually to breathe the air of ill-ventilated rooms, confined sleeping apartments, crowded low-roofed schools, or other places in which numbers are assembled together, and where ventilation is not particularly attended to. A long-continued and constant residence in such places most certainly shortens life by several years, and not unfrequently terminates it rapidly, by giving rise to consumption and other fatal disorders.

86. It must not be supposed, however, from what has been said, that the carbonic acid given off from the lungs is to be viewed as a merely noxious material. If it were retained, death would undoubtedly take place; but if no carbonic acid were formed, we shall find that the heat of our bodies could probably not be maintained. When charcoal is burned in atmospheric air, the changes which occur seem to be almost precisely similar to those that are produced by respiration. Oxygen disappears, and carbonic acid is formed. It seems reasonable, therefore, to conclude, that the heat produced in both cases is connected with these changes. That the production of animal heat bears some resemblance to combustion, is rendered probable by the following considerations:—1st, It has been determined by experiment that the charcoal contained in the carbonic acid formed during a given period by respiration, would give out, when burned, fully more than half the heat produced by the animal in that period. It takes no less than about eleven ounces of carbon to form the carbonic acid of an ordinary man's daily respiration. Dr. Milne Edwards thinks that this, and the superabundant

147. Illustration of the importance of fresh air.
148. Necessity of ventilation.
149. Necessity of carbon to animal heat.
150. Analogy between combustion and respiration.

oxygen which is absorbed by the blood, (which probably combines in great part with hydrogen to form water,) will account for nine-tenths of the heat an animal produces, the remaining tenth probably being the product of the friction of the different parts of the body, the changes occurring in secretion, &c. 2dly, This view is supported by the fact, that the temperature, in the different classes of animals, very accurately corresponds to the quantity of oxygen consumed. The temperature of birds is highest, and they consume most. The young, among the Mammalia, consume the least, and have the temperature lowest. Indeed, it may be remarked, that the young of most of the Mammalia, including children, have much difficulty in supporting any great degree of cold when separated from their parents; and where incautious exposure takes place, the mortality among them is found to be very great. Reptiles, which consume little oxygen, have a temperature only a few degrees above the medium in which they live; and the same may be said of fishes, with the remarkable exception of the Cetacea, (whale, porpoise, &c.,) which have a high temperature, but consume much oxygen, as they breathe the air by lungs.

87. It has been thought, however, that as the carbonic acid is given off in respiration, and the oxygen disappears at the same time, the temperature of the lungs ought to be much higher than that of other parts, and it was to meet this difficulty that Dr. Crawford proposed his celebrated *Theory of Animal Heat*. He maintained that the capacity for heat (as chemists call it) is greater in arterial than in venous blood;* that as this enlargement of capacity

* What is meant by capacity may be rendered intelligible thus:— If we mix one pound of water at the temperature of 60 degrees, with another pound at 91 degrees, the resulting temperature will be exactly the medium, or 75½ degrees. But if we mix a pound of water at 60 degrees with a pound of quicksilver at 91 degrees, the resulting temperature will be only 61 degrees, because the capacity of water is so much greater than that of quicksilver, that the heat which raises the quicksilver 31 degrees will raise the water only 1 degree.

151. How is this theory sustained?
152. What of Crawford's theory?
153. Explain the note.

takes place in the lungs, at the same moment as the heat is generated, a considerable portion of it must be absorbed; and that this latent heat comes to be given out, as the arterial, in its course, is again gradually converted into venous blood.

88. It will be observed, that Dr. Crawford's theory supposes, 1st, that the capacity for heat in arterial is greater than in venous blood, which subsequent observation has not shown to be the case. Dr. Davy states the capacity of both to be very nearly the same. 2d, It supposes that the carbonic acid given off during respiration is *formed in the lungs*, from the direct combination of the oxygen of the atmosphere with the carbon of the blood, which also appears to be incorrect, for it has been shown, by Dr. Edwards and others, that carbonic acid is produced in large quantities, even when an animal is made to breathe a gas containing no oxygen. A frog can be made to breathe nitrogen or hydrogen gas, even for several hours together, without losing its vitality; and in such cases, it is found that nearly as much carbonic acid is formed as when the animal is allowed to breathe atmospheric air. It therefore seems probable that the carbonic acid is *formed in the blood*, and is merely given off or separated at the lungs. There is another theory that has been proposed by Lagrange and Hassenfratz, two German physiologists, and which is supported by the fact ascertained by Professor Magnus, that venous and arterial blood both contain carbonic acid and oxygen, but that the carbonic acid is in larger and the oxygen in less quantity in the venous than in the arterial blood, which seems to avoid the difficulties involved in Dr. Crawford's theory. The oxygen, these physiologists suppose, when it is absorbed by the blood in the lungs, exists there only in a loose state of combination; as it circulates, the union with the carbon, &c., of the blood is supposed to become more intimate, the carbonic acid being thus formed probably in the capillaries; and the heat comes thus also to be gradually disen-

154. Objections to this theory.
155. What are the other opinions stated.

gaged, and diffused through every part of the body. Professor Müller calculates that the quantity of carbonic acid which has been ascertained to exist in each cubic inch of venous blood, is sufficient to account for the whole quantity exhaled from the lungs. Professor Liebig, a high authority, takes nearly the same view of this subject. Many other facts, however, prove that both secretion and the nervous system are connected, directly or indirectly, with the production of animal heat. We can only state generally, also, that the body possesses the power of keeping down its heat to nearly the natural standard, even when exposed to a very high temperature. Sir Charles Blagden remained, without any great inconvenience, in a room, the temperature of which was 52 degrees above that of boiling water, until eggs were roasted hard, and a beefsteak made ready by blowing air on it. Indeed, the heat of his body, though the temperature of the apartment was 264 degrees, rose only three or four degrees above 98 degrees, its natural standard. It has been found that the principal agent in keeping down the temperature, is the immense evaporation that takes place from the lungs and skin. Accordingly, when the skin is varnished, or the air of the apartment is saturated with moisture, so as to prevent evaporation, a temperature one-half so high can hardly be borne.

89. Having now given a short but connected account of the physiology of the circulation and respiration, we cannot but remark how varied and how complicated are the agents employed, and yet how accurately each of these performs the part assigned it. Such investigations as those with which we have been occupied, form the proper foundations of natural religion. No one can rise from the study of these parts of the animal frame, without intensely feeling that *design*, and design of a kind the most exquisite, guides every motion and change of the vital fluid. Never did any piece of machinery invented by man, indicate with greater precision the intentions of its maker.

156. How is the living body protected from high heat?
157. From what surfaces?
158. What reflections are suggested?

90. The voice is produced in what is called the larynx, at the top of the windwipe, (Fig. 20, *a*.) The air, in passing through its opening, (*glottis*, Fig. 11, *e*, and Figs. 22 and 23,) causes parts called vocal ligaments to vibrate, and to give out the different varieties of sound. These sounds can be further modified by the parts in the mouth, &c., so as to produce articulate speech. Singing-birds have a simple larynx at the top, and a complicated one at the bottom, of the windpipe.

91. When foreign bodies, such as cherry or plum stones, get into the larynx or windpipe, they cause excessive irritation, and not unfrequently death. A few years ago, a woman came under the care of Mr. Liston, who stated, that six months previously she had been nearly choked by a piece of bone, while eating some hashed meat; that when she was almost suffocated it had passed downwards into the windpipe, and that she could since then feel it lodging at the top of the chest, on the right side. Her statement was so precise that Mr. Liston resolved to attempt its extraction. He cut down into the windpipe at the bottom of the neck, passed his instrument downwards three or four inches towards the right lung, and felt the bone. But he found his instrument opened in a wrong direction to seize it. This difficulty had, however, been anticipated by the accomplished operator. Another pair of forceps, opening differently, was produced; the bone was seized and extracted, and the woman left the hospital in a few days quite recovered.

92. Other affections of the top of the windpipe produce suffocation, and among these, by far the most common and fatal is *croup*. This disease consists in inflammation and swelling of the inner or mucous lining of the larynx and windpipe. When allowed to gain ground for even a few hours, the surgeon meets with few more rapidly fatal diseases. The cause of this will


Fig. 22.


Fig. 23.

159. What of the structure concerned in the voice?
160. To what accidents is the larynx liable?
161. Do foreign bodies ever enter the windpipe?

easily be understood, from looking at Figure 22, which shows the natural size of the opening (rima glottidis) through which all the air had to pass, in a weakly child 11 years old. Figure 23 is the same seen from within. The least diminution of this opening is fatal.

93. When the inner or mucous membrane of a few of the larger branches of the windpipe is slightly inflamed, it is called *a common cold;* when the inflammation is greater, and extends to the lesser air-tubes (bronchi), it is called *bronchitis*, and is often denoted by considerable wheezing in the breathing;* when the air-vesicles, and the substance which connects them, become inflamed, it is called inflammation of the lungs (*pneumonia*). The last is a very fatal disease, if not early checked. The importance of early attention to it will be understood from this, that it consists of three stages, in the first of which the part of the lungs affected is merely engorged with the watery serum of the blood. A smart bleeding will frequently at once remove this. But if allowed to remain, this rapidly passes into the second stage, in which the lung becomes solid like a piece of liver (*hepatization*), and ultimately into the third stage, when the solid portion is infiltrated with matter (*pus*). The two latter stages are comparatively seldom recovered from.

94. When the membrane (pleura) covering the lungs and lining the inside of the chest is inflamed, it is called *pleurisy*, or *pleuritis*, and is denoted by the sharp cutting pain which is felt when we draw a breath. If uncombined with pleuritis, the pain in pneumonia (inflammation

* Millers, masons, sawyers, grinders, and others who are exposed to the inhalation of various kinds of dust, are very subject to this disease, and have their lives much shortened by it. Dry grinders seldom live beyond 30 or 35 years. In M. Lombard's returns for Geneva, the average longevity of stone-cutters is stated at 34 years, of sculptors at 36 years, and of millers at 42 years; while painters live, on an average, to 44, joiners to 49, butchers to 53, writers to 51, surgeons to 54, masons to 55, gardeners to 60, merchants to 62, protestant clergymen to 63, and magistrates to 69 years.

162. What disease occurs here?
163. What of cold, and bronchitis, pneumonia, and hepatizations?
164. What of the mortality from bronchitis?

of the lungs) is not great. It is rather tightness of the chest, and oppression of the breathing, that are felt. These are caused by the difficulty the air finds in getting admission into the condensed air-vesicles. From the same cause, pneumonia is generally attended by rapid and heaving breathing. As the quantity of air that can be brought into contact with the blood is diminished, fuller and more frequent inspirations require to be made. If the hepatization extends to the whole of one lung, then there can be no motion of the chest on that side, as the air enters only to the other lung. These signs are of especial importance in children. Whenever the breathing of a previously healthy child becomes rapid and heaving, alarm should be felt for its safety.

95. The branches of the windpipe have another coat below the inner or mucous one, which, like that of the intestines, is muscular, and can, it is thought, contract and diminish their size. This contraction is supposed to be the cause of the sudden difficulty in breathing, so often felt by asthmatic persons. In asthma, however, other causes combine to produce this difficulty; for, 1st, there is generally more or less habitual inflammation of the larger air-tubes; and, 2dly, from the repeated violent fits of coughing, the air-vesicles become distended or ruptured, so that the cavity of the chest is permanently filled to a considerable extent with these distended vesicles (*bullæ*). The surface of the lungs of old asthmatic persons may be seen studded with these, like little bladders, sometimes as large as walnuts.

96. The only other disease of the lungs we shall notice, is the almost invariably fatal one, consumption (*phthisis pulmonalis*). This disease consists in the formation, in the lungs, of a peculiar substance called tubercle. Tubercles are at first small semi-transparent bodies, like pins'-heads; but as they increase in size and number, they unite, and form masses generally like yellowish cheese, occasionally as large as a walnut or an orange. At a later period, this cheesy matter becomes softened,

165. What of pleuritis, asthma, and consumption?

and is coughed up, leaving cavities in the lungs more or less extensive, under the irritation of which the patient sinks. Consumption, from very accurate calculations, is known to cause about one in every five deaths in Great Britain, so that some knowledge of the causes which produce it is important to almost every one. From extensive statistical inquiries made in Geneva by Dr. Lombard, he has found that the average number of consumptive cases occurring in all the different professions of that town, is 114 in the 1000. In some it rises much above, while in others it falls greatly below, this average number. Thus, among varnish-painters no less than 37 out of the 100 were found to have died of this complaint, while of gardeners only 4 in the 100 fell a sacrifice to it. The causes which principally tend to produce consumption, Dr. Lombard finds, are, 1st, breathing air in which mineral, vegetable, or animal powders are floating: among polishers, sculptors, stone-cutters, plasterers, watch-hand-makers, &c., the proportion of consumptive complaints is 177 in the 1000. 2d, Sedentary occupations seem to have a great effect in producing this disease, the mortality among clerks, printers, tailors, engravers, &c., being 141 in the 1000; while among such active professions as carpenters, blacksmiths, slaters, agriculturists, &c., the average proportion is 89 in the 1000. 3d, Indigent persons seem about twice more liable to consumption than those living in easy circumstances: annuitants in Geneva, who may be reckoned as generally leading an easy, comfortable life, average only 50 consumptive persons in the 1000. 4th, The more or less impure state of the air breathed, its temperature, dryness, &c., seem to influence considerably the production of consumption. In professions in which life is spent in shops or manufactories, the proportion of cases is 138 in the 1000; while in those professions in which life is spent principally in the open air, only 73 in the 1000 become its victims. An atmosphere loaded with animal emanations, such as is breathed by butchers, tanners, candle-makers, &c., seems to act rather

166. Causes of consumption, physical and chemical in their action.

as a preventive to this complaint, the average among these professions being only 60 in the 1000. Breathing a moist air seems also a preventive circumstance, as weavers, dyers, bleachers, watermen, &c., are found liable to it only in the proportion of 53 in the 1000; while those who breathe a hot dry air, such as toolmakers, enamellers, file-smiths, &c., have 127 in the 1000 affected. These deductions may be considered as, at least, approximations to the truth, and they in general agree with what might have been expected, as we know that even in the lower animals consumption can be produced at pleasure by general debilitating causes, or by irritants applied directly to the lungs. A large proportion of the monkeys brought from their own warm to this cold and changeable climate, die of this scourge of our race; and M. Flourens, a French physiologist, has shown, that by keeping chickens in a dark and damp cellar, and upon a scanty diet, they are rapidly carried off by this affection. Though the lungs are the parts most usually affected by this disease, it is a mistake to suppose that it is a merely local complaint. Very commonly, the cheesy matter is found, at the same time, in the liver, mesentery, and many other parts; and there can be little doubt that the essential cause of the whole is a particular form of constitution, either inherited from parents, or brought on by irregular habits, want of fresh air and exercise, or other diseases and circumstances that enfeeble the body. Where the predisposition to this disease is very great, we see whole families cut off by it; but when the predisposition is less, we often notice only those affected that follow occupations, or have contracted habits, that impair their health.*

* We have said that consumption is a hereditary disease, or arises from a peculiar constitution transmitted from parents to children. This is what is called the scrofulous constitution, which can often be detected by a practised observer, but of which it is not easy to give any definition, except that the formation of tubercular (cheesy) matter in any part always denotes it. When much developed, and when it

167. Observations upon inferior animals.
168. Consumption constitutional and hereditary.
169. What practical reflections are suggested?

97. In concluding the subject of respiration, we may mention that a French physician, named Laennec, invented a simple instrument, called the stethoscope, which enables us to ascertain very accurately, from the sounds of the air passing through the lungs, what is going on within. Different diseases are denoted by the modifications of sound they produce, often with as much precision as if we saw through the walls of the chest.

The mechanism of respiration may be beautifully seen in the hare. After skinning, &c., open the belly, take out the intestines, liver, &c., and cut through the back-bone high up with a strong knife. The diaphragm, separating the belly from the chest, will then be seen. To show the parts contained in the chest, next take away the fore-legs, and cautiously detach the ribs from the breast-bone, on each side, except at the top and bottom, breaking or snipping through with scissors the detached ribs near the back-bone, and removing them. The breast-bone will thus be left in its place, supported by a rib or two at the top and bottom, and the division of the chest into two halves by the pleura—the heart lying in its bag or pericardium—as well as the appearance and position of the lungs, will be seen. Great care must be taken in opening into the chest, and in cutting the ribs posteriorly, not to injure the lungs. To show the action of the lungs, the windpipe must now be cut down upon in the neck, cut through, and detached, and a small tube tied into it. When this is gently

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affects the glands of the neck, it is vulgarly termed "king's evil." Constitutions are variously tainted with it, however, from a very slight to a very high degree; and it may easily be conceived how generally the taint is diffused, when we have stated that one in every five dies in this country from one of its forms. There are many other diseases, the tendency to which is derived from parents, such as asthma, insanity, gout, &c.; and there can be little doubt that this class of diseases constitutes the great bar to the physical improvement of the human stock. Until correct views on this subject become more general, little hope of improvement can be entertained. At present, persons in every rank make eager inquiries as to the worldly condition, &c., of those who are likely to form their partners for life; but how seldom does it happen that the tendency to even serious hereditary disease forms a bar to their union, or that persons even take the least pains to satisfy themselves whether such exists! The great part of mankind neglect far too much the fact that they are animals, and that they are therefore subject to those general laws which regulate the transmission of peculiarities or diseases to their children. Hence, from this serious error, they fail to take the precautions which are necessary to secure an approach towards physical perfection in their own progeny, and the neglect of which they would be ashamed of, even in regard to their dogs and their horses.

170. What of Laennec's instrument?

blown into, the lungs will be seen to be inflated. A much more elegant mode of showing their action, however, is, carefully to take out both windpipe and lungs, and to attach them as represented in Fig. 24, where *a* is a bottle, six or seven inches high, and about three wide, such as is used by druggists, with the bottom cut off; *b* is the hare's lungs (with the windpipe left moderately long) tied to a notched tin tube (*c*), that passes through a cork accurately fitting the neck of the bottle; *d* is a wooden piston, three-fourths of an inch thick, covered with soft leather, which is stuffed with hair, and oiled to make it fit accurately. When the handle of the piston is drawn quickly down, the air rushes by the tube and windpipe into the lungs, and inflates them, and this can be repeated by pushing the piston gently up, and then again drawing it quickly down. The bottle must be of the same width throughout, and the lungs must not be cut or injured in any part. The lungs should be in the bottle, and the windpipe tied on the tube, before the cork is fitted into the bottle. This is a remarkably striking experiment, and should be seen by every one who wishes to form a just conception of respiration.

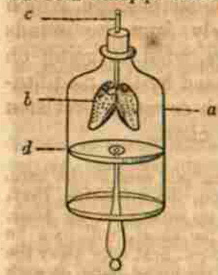

Fig. 24.
Hare's lungs in a bottle.

The power of oxygen in supporting combustion, and of carbonic acid in extinguishing it, should also be shown by introducing a lighted candle, fixed on a wire, into jars of these gases.

That the expired air contains carbonic acid, may easily be shown by breathing through a tube immersed in newly prepared lime water. The carbonic acid throws down the lime in the form of carbonate of lime.

By placing the ear to the upper part of the chest of a young person, the murmur produced by the air rushing through the air-vesicles may be heard; or the stethoscope may be used for hearing this, as well as the sounds of the heart.

The air-cells of birds may be seen in the pigeon, by opening the belly on one side, and then (while pressure of the fingers on the ribs prevents any escape of air from the lung on that side) blowing air into the windpipe, as directed above.

The gills of a cod or haddock (recent or dried) should also be examined.

Preparations of the bronchial tubes are generally made by anatomists with wax. These, however, have the disadvantage of being easily broken. We have used, instead of wax, some of the metals. Equal parts of tin and lead answer well for the larger bronchi. Take a sheep's lungs, clear away fat, &c., but taking care not to injure them, and cut off the windpipe three or four inches above the lungs; dry the interior of the windpipe by introducing pieces of lint on the end of a stick, and afterwards allowing it to remain exposed to the air for a few hours. Then transfix the windpipe at the upper part with two darning-needles crossed, to hang the lungs by; fasten the needles to the ring of a retort-stand; fasten a wide-mouthed tin funnel, supported by another ring of the retort, in the windpipe, and pour in the melted metal; boil the lungs for two hours, cut out the preparation, and varnish with wax dissolved in boiling spirits of wine. A much more delicate preparation can be made in the following manner:— Instead of tin and lead, take the composition called the *fusible metal*,* and pour it into the lungs, and then place these in a large pot of water, to be kept boiling for an hour. The air is thus in a great measure expelled; and as the metal melts at the boiling point of water, it finds its way into the most minute ramifications. When heated, the air in the air-tubes causes the lungs to become buoyant, which prevents the metal getting properly into the lower bronchi. To obviate this, the lungs may be enveloped in a cloth, which should be loaded with heavy weights, to keep them in the upright position. As the metal is extremely brittle when hot, the lungs should not be taken out of the pot till they are cold; then hang them in some place where flies can deposit their eggs, moistening the outside daily, and allow them to remain until the maggots eat away all the flesh; after this, hang them in water until the preparation can be easily cleaned. In making both preparations, about one and a half pounds of metal are required, and the tin filler should be heated to make the metal run the easier. If any of the large branches are broken, any tinsmith will easily solder them. When well managed, preparations we have made in this way have a truly wonderful appearance; the bronchial tubes, though beautifully distinct, and as fine as hairs, presenting almost a solid mass. The existence of air-vesicles has been doubted by some authors, and these preparations seem to us to support this opinion.

Other illustrative figures for this section will be found in Bell's Anatomy, vol. i., page 599; Dr. Smith's Philosophy of Health, vol. i., page 243; "Animal Physiology," in the Library of Useful Knowledge, pages 88, 89, 90, 92, &c., &c.

[Some of the foregoing experiments are unsuited for schools, but models of the respiratory apparatus, made of papier maché by Dr. Azoux, of Paris, can now readily be obtained in this country.]

SECTION V.

SECRETION AND NUTRITION.

98. We have seen, in the preceding sections, that there are arrangements for circulating the blood and for keeping it pure. The great object in these arrangements seems to be, that the substances required in the different parts of

* The *Fusible Metal* may be composed of two parts bismuth, one lead, one tin, and one quicksilver, to be all melted together and well mixed.

the system may be separated from the blood in a proper state. There is a class of bodies, known by the name of glands, whose office appears to be principally to form different secretions. Thus, the liver is a gland, which is said to secrete (separate) bile: the salivary glands, we have seen, secrete saliva; and so on with the others. It would be a mistake, however, to suppose that secretion is performed only by glands, for thin membranes, without any glandular structure, produce numerous secretions; and the deposition of the solid parts of the body takes place without the intervention of any thing like glands. It seems to be the capillary vessels, themselves, in these cases, that are employed; and even in glands, however minutely we examine their structure, there can be detected almost nothing but endless subdivisions of circulating vessels, and ducts for collecting and carrying off the secreted fluid.

99. It will be impossible for us even to refer individually to the numerous substances produced by secretion. We shall, therefore, mention particularly only a few, and make some general observations regarding the whole.

100. The liver (Figs. 12, *l*, and 21, *c*) is the largest gland in the body. We have seen that it secretes the bile, which probably serves important purposes in digestion. The numerous ducts of the liver unite and form one large duct, called the hepatic duct (Fig. 12, *h*), from which the bile passes into the common duct (*i*), or into the gall-bladder (*m*), to be poured, when required, into the upper part of the intestinal canal. The bile is an alkaline fluid, which contains, besides other substances, a peculiar resinous principle. Unlike other secretions, it is formed from the venous blood. The whole veins of the stomach and intestines, instead of going directly to the right side of the heart, first unite to form one great trunk (vena portæ), which divides, like an artery, in the substance of the liver; and

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171. What sources of secretion are pointed out?
172. Define secretion, nutrition, &c.
173. What is peculiar in the structure of the liver?
174. What is the bile and its uses?
175. Describe the circulation of the liver.

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these branches, by which the bile is secreted, again unite, and join the veins going to the heart in the ordinary way. In some species the veins going to the kidneys have a similar distribution. From this, and for various other reasons, it is strongly conjectured that the liver assists the lungs in purifying the venous blood, by depriving it of a portion of its carbon; and, accordingly, we always notice the liver larger in animals in proportion as the activity of their lungs diminishes. The carbon uniting with oxygen forms the carbonic acid given off from the lungs: it seems to escape from the liver in union with another gas called hydrogen, forming the resinous and other principles of the bile. We have before stated that less oxygen is consumed, and of course less carbonic acid is produced, when the temperature is high than when it is low. Hence, probably, a chief cause of the diseases of the liver Europeans are liable to in warm climates; for if less carbon be given off at the lungs, more will have to be secreted by the liver; and any part required to do more than its ordinary duty is apt to become deranged. It is thought that about six or eight ounces of bile are ordinarily secreted daily. Another analogous substance, called *urea*, is secreted by the kidneys, which are glands that also probably assist in purifying the blood. It is probable that both the resinous matter in the bile, and the urea in the urine, exist ready formed in the blood, and are merely separated by their respective glands; as, when the kidneys of dogs have been taken away, urea has been detected in the blood, which could not be the case if the kidneys formed it. It sometimes happens, especially in drunkards, that one or both of these glands become diseased, and are incapable of separating the peculiar fluids mentioned; and then these, being retained in the system, act as poisons, producing insensibility and death. In the case of the liver, this forms one cause of jaundice; but jaundice is more commonly caused by an obstruction to the flow of the bile through its ducts. The passage of gall-stones (which are

176. Theory of the liver, assisting to purify the blood.
177. What of the secretion by the kidneys?
178. Examples of the failure of these secretions and effects.

only bile solidified) from the gall-bladder through the common duct (Fig. 12, *i*), is a common cause of obstruction. When the substance of the liver becomes diseased, the flow of blood through its veins is also often obstructed, and this very generally gives rise to dropsy.

101. What has been said must suffice in regard to the larger glands; smaller ones are scattered in almost every part of the body. The whole extent of the intestinal canal, and of the skin, is found to be studded with bodies having a glandular structure, and producing secretions.

102. Some secretions are evidently produced only in particular emergencies, as we see with the increased secretion of bony matter when a limb is broken; other secretions are uncommon in their nature, as in the case of such fishes as the torpedo, or of the firefly, the former of which can produce at pleasure powerful electrical discharges, and the latter a substance that gives out light; while in other instances, again, secretions become unusual in their situation, or of a morbid kind. Of a secretion unusual in its situation a curious instance occurred some years ago in France. A woman who was suckling had the secretion of milk transferred from her breast to one of the lower extremities, from which her child continued to be supplied. Of morbid secretions we have examples in ossification of the valves of the heart, in consumption, in cancerous, brainy, and other tumours, and, unfortunately, in too many other cases.

103. The secretions are much influenced by our mental states. Every one has felt the flow of saliva increased from savoury odours, or the flow of tears from distressing feelings. A cheerful state of mind is peculiarly favourable to the proper performance of the function of secretion; and we therefore learn how important it is to avoid such things as distract, or agitate, or harass us.

104. As to the agent which produces or directs the different secretions, we have no very accurate information.

179. Peculiarities of secretion and number of glands.
180. Curious instance of transfer of secretion.
181. Effects of the mind.
182. What is said of galvanism?

In one instance, at least, Dr. W. Philip found that its place could be supplied by galvanism. He cut the principal nerves going to the stomach, and the secretion of gastric juice was completely stopped; but the secretion was restored when a galvanic pile was made to communicate with the lower extremities of the nerves. Of late years it has been discovered that the operations of galvanism are much more various and subtle than was formerly supposed, and it therefore seems not unreasonable to conjecture that its agency may be important also in secretion.

Suitable views of the liver will be found in Lizars's Coloured Plates, page 86, and of the kidneys, at page 88.

SECTION VI.

EXHALATION AND ABSORPTION—THE SKIN.

105. By exhalation is meant the escape of some portion of the contents of the blood-vessels (generally little altered), probably through pores in their sides. When a fluid, coloured with vermillion, is injected into the blood-vessels of a dead animal, the fluid portion will pass out of them, and is said to be exhaled, while the vermillion is retained; or when a solution of phosphorus is thrown into the veins of a living animal, in a few seconds fumes of phosphorous acid are given off from its lungs. By absorption is meant the removal of the soft or hard parts of the body, or of substances placed in contact with these parts. When a fat person becomes lean, or the fluid in a dropsical person's belly has disappeared, the fat and the fluid are said to have been absorbed.

106. The three most important exhaling and absorbing surfaces, are the intestinal canal, the lungs, and the skin; but these processes are active also in the chest, belly, and other cavities. We have already explained the structure

183. Define exhalation and absorption.
184. Instances of both.

of the intestinal canal and lungs, and the skin will be treated of at the close of this section, so that it will be necessary at present only to say, that the skin has a thin outer covering, called the cuticle, or epidermis (the part raised by blistering), which has no feeling, and little vitality; and another thicker part underneath, called the true skin (the part which tanners convert into leather), which is plentifully supplied with nerves, blood-vessels, &c.

107. From what has been said, it will be seen that the mechanism of exhalation is very simple, the fluid merely passing through the sides of its vessels. In every part of the system an active absorption is carried on by the same means, the fluid removed merely passing through the sides of the veins, to be carried off by the internal current. It was at one time supposed that absorption was exclusively carried on by a system of vessels, which received the name of absorbents; but this is now known to be quite incorrect. Allusion has already been made to one portion of these absorbent vessels, connected with digestion, which are called lacteals (Fig. 13). Similar vessels in other parts of the body (some of which are seen in Fig. 13, *h*) receive the name of lymphatics, from a fluid called lymph, which they convey; and in their course towards the thoracic duct (Fig. 13, *g*), in which they almost all terminate, they pass through glandular bodies, found in numbers in the hams, groins, armpits, on the sides of the neck, &c. It is these glands about the neck that so often swell and inflame when there is disease of the gums, or eruptions on the head, or when there exists a highly scrofulous habit of body.

108. The veins appear to take up all fluid matters indiscriminately that are brought in contact with them; the lacteals take up principally (if not solely) chyle; the office of the lymphatics seem to be chiefly to mould the different parts of the body into their proper forms, and the lymph contained in them is probably the removed animal matters which, it is supposed, may undergo some changes while passing through the lymphatics and their glands, that ren-

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der them fit to be mingled with the blood. From the late researches of Fohmann, Panizza, and Lanth, it would appear that the lymphatics commence by minute plexuses, and that these at their origin do not communicate with the arteries and veins, but begin by shut extremities. In the frog, and in some other reptiles, there have been discovered parts, connected with the lymphatics, that pulsate irregularly, like hearts. The frog has four of these, which seem to be used for propelling the lymph.

109. Absorption and exhalation, in a healthy state, generally balance each other, so that a full-grown person's weight, notwithstanding the quantity of food consumed, will frequently, for years, vary only a few pounds. The conditions which promote the one, generally impede the other. When the body is saturated with fluid, absorption goes on slowly; but exhalation, under the same circumstances, takes place rapidly. M. Magendie found that when a quantity of water was thrown into an animal's veins, absorption was either much impeded, or altogether suspended; and, on the other hand, when the blood-vessels were partly emptied by bleeding, the effects of a poison, that usually showed themselves at the end of the second minute, were distinctly perceived before the thirtieth second. A frog, kept for some time previously in dry air, when its legs are immersed in water, will in a short time absorb nearly its own weight of the fluid.

110. We have already spoken of the absorbing powers of the intestinal canal. The next in importance, as an absorbing surface for external substances, is in the lungs, and, of course, the matters absorbed are generally conveyed in the form of vapour. When a fluid poison, however, is injected into the windpipe, it acts with fearful rapidity. It is through this surface that substances diffused in the atmosphere usually produce their effects on the system. The vapour of turpentine, breathed along with the air of a room, may be detected in the urine within a short time afterwards, and the concentrated vapour of such poisons as prussic acid will instantly kill an animal if inhaled. It is

188. Relative amount of these two processes.
189. Proofs of absorption in the lungs.

probable also that the various poisons which produce fever, measles, small-pox, and other infectious disorders, are in this way introduced into the body, the smallest quantity frequently sufficing for this purpose. We can conceive the small quantity of the poison required, when we notice that the least particle of the matter of small-pox, placed in a scratch on the skin, gives rise to the same disease. In proof of the action of poisons, when inhaled by the lungs, the following facts may be stated:

111. M. Magendie contrived some experiments, in which dogs were confined in the upper part of a barrel, the lower part being filled with putrefying animal substances, which were separated from the dogs by a grating. Confinement in this situation, from the absorption of the putrid effluvia, produced death generally about the tenth day. The animals took food, and were even lively, but became much emaciated before death. The same physiologist produced symptoms exactly resembling those of yellow fever, by injecting a few drops of putrid water into the veins of dogs.

112. A nurse in one of the Dublin hospitals, apparently in excellent health, was desired by the physician to assist a patient, labouring under fever, to turn in bed. Being very feeble, he endeavoured to support himself by placing his arms round the nurse's neck, when she suddenly drew back, struck by the offensive odour from his person, and exclaiming that she had caught fever. She instantly became cold, pale, and ghastly, and, appearing about to faint, had to be removed to her room. Malignant fever, of a very severe description, succeeded, and lasted for thirteen days.

113. In the island of St. Lucia, in the West Indies, two boatmen were employed hauling their canoe up on the beach, close to a dangerous swamp, when they perceived a small cloud of vapour approaching, which gradually enveloped them. One immediately fell down insensible, and the other was so much affected as to be unable to render

190. Examples of poisons thus acting.
191. Instances of poisonous exhalations.

him any assistance. The vapour soon passed away, and both men recovered so far as to be able to walk home. The one most affected, however, was seized with fever, and died within forty hours afterwards.

114. Repeated instances occur in the West Indies of twenty or thirty workmen being employed in cutting drains or canals in these infectious swamps, nine out of ten of whom will be seized in a few days with the most dangerous forms of tropical fever. Chiefly from these pestilential fevers, also, the probability of life to Europeans in the West Indies is very low. It appears, from the most accurate army returns, that a young man's chance of life, which in this country would probably be about forty years, is reduced in Jamaica to about seven years.

115. In such marshy districts as the fens in Lincolnshire, or the Pontine marshes near Rome, the poison diffused in the atmosphere operates with intensity chiefly after sunset, and produces dreadfully fatal fevers and agues. We see also, in the natives of these districts, the effects which the slow operation of the poison produces on the health. Their appearance in highly infected districts is miserable in the extreme. Stunted in their growth, with swollen bellies, stupid expression, and jaundiced complexions, they linger out a miserable existence, and can anywhere, at a glance, be recognised. Happily their sufferings terminate life quickly. In Rome, chiefly from this cause, the annual mortality of the whole population is stated at one in twenty-five, while in the whole of England and Wales Mr. Rickman states that it is only one in sixty. It is a curious circumstance that these poisons generally lie latent or inactive in the body for some time. In the fevers of this country, the latent period may vary from a few days to some weeks: while in marsh fever, a person will often have left the infected district, six, twelve, or more months, before he is seized with it.

116. We have entered into these details in order that it may be seen, 1st, that unnecessary exposure to air infected with the poison of fever, is both improper and highly

192. Reflections deduced therefrom.

dangerous; and, 2dly, to show how important to health is pure air, attention to cleanliness, and the removal of all putrefying animal and vegetable matters from the vicinity of our dwellings. In a very filthy part of Constantinople, called the Jews' quarter, the plague constantly prevails more or less, and the same may be said of typhus fever in some confined and dirty parts of London, Edinburgh, Glasgow, and most other large towns.

117. In man, the absorbing powers of the skin are much more limited than those of the lungs. When the cuticle is entire, indeed, it appears to absorb almost none, unless the substance be rubbed on it with force, or be of a very irritating nature. When the cuticle is removed, however, it absorbs readily. This is the reason why the most virulent poisons can be handled with impunity, only while the cuticle is entire. Surgeons often suffer severely from this cause, when, in opening dead bodies, they accidentally puncture or cut themselves, even in the slightest degree. The poison introduced by the cut part inflames it dreadfully, and death not unfrequently occurs within a few days. It is for the same reason that a slight scratch must be made through the cuticle before a child can be inoculated.

118. The exhaling powers of both the skin and the lungs are very considerable. In winter, we notice the watery vapour coming from the lungs condensed by the cold air; in summer, we see how much fluid escapes from the skin in the form of perspiration. Independently of this, however, from thirty to sixty ounces of watery fluid are calculated to pass off daily from the skin in the form of insensible perspiration. This insensible perspiration may be seen to be condensed, when the point of the finger is moved along the surface of a looking-glass, at about the distance of an eighth of an inch, and also when we handle any polished steel instrument; or, still more decisively, when the arm is confined in a glass jar. It is the condensation of this insensible perspiration that makes the inner surface of a M'Intosh cloak damp when worn in frosty weather

193. Effects of the cuticle in preventing absorption.
194. Danger of wounds or abrasions of the skin
195. Insensible perspiration, its extent.

Dr. Smith has performed some interesting experiments on the subject of exhalation, from the skin and lungs jointly. Eight workmen in the Phœnix Gas-works, London (where they must work hard, and be exposed to a high temperature at the same time), were weighed before going to work, and immediately afterwards. In one experiment, in November, they continued to work for an hour and a quarter, and the greatest loss sustained by any one man was two pounds fifteen ounces. In another experiment, in the same month, one man lost four pounds three ounces in three quarters of an hour; and in an experiment of the same kind, in June, one man lost no less than five pounds two ounces in an hour and ten minutes.

119. We shall conclude this section, by stating a few other circumstances connected with the structure and functions of the skin. We have mentioned that the external layer of the skin is called the cuticle. M. Breschet, a French author, who has very carefully investigated the structure of the skin, considers the cuticle to be of the same nature as the horny matter which forms the nails, the hairs, feathers, horns, &c., of animals. It is secreted by particular organs, and when intended to be coloured, it is mixed with colouring matter (which also is secreted by distinct organs) while in a fluid state. The arrangement of the cuticle, in different parts of the human body, is well worthy of attention. Where feeling is to be exercised, it is thin and delicate; over the joints it is lax and movable; on the palms of the hands and soles of the feet, even in the infant, it is thick and hard, and these properties are greatly increased by constant use. Simple as this last provision may appear, it seems doubtful whether the want of it would not have interfered materially with the exercise of many of our most useful arts.

120. Between the cuticle and the true skin, formerly mentioned as the part of animals that is tanned, is found the layer that gives the colour to the different varieties of

196. Experiments on the amount of insensible perspiration and exhalation from the lungs and skin.
197. What of the cuticle and its distribution?

the human species, &c. (*rete mucosum*). In Europeans it is generally of a light colour, in Negroes it is black, and in other races it is intermediate, or of other shades. The colour of the Negro does not depend on the blackening of the cuticle by the sun, for his cuticle is seen to be as transparent as a European's when raised by a blister; and we observe, also, that the secretion of the black colouring matter does not take place in the Negro child until a day or two after birth.

121. The *cutis*, or true skin, is the third and most important layer. Besides its uses already referred to, it has a very large supply of blood sent to it; is a surface of great sensibility, intimately sympathizing with the internal organs; and, from its exposed situation and extent, is peculiarly liable to be affected by external influences. Perhaps no other surface in the body is so much concerned in the production of internal inflammatory disorders, and perhaps the agents that above all others tend to produce these, are the various degrees, and especially the sudden applications, of heat and cold. When heat is applied suddenly and extensively, so as to give rise to a burn or scald, the heart's action is frequently extinguished within a few hours, even although the burn, in any one portion, is altogether superficial and unimportant. Mr. John Hunter gives a striking proof of the effects produced by a sudden change of temperature on the skin. He took an eel, which was swimming in water a little above 30 degrees, and plunged it into water about 60 degrees, a temperature in which it habitually lives with ease. The sudden change, however, gave such a shock to its system, that the animal instantly expired.* In these cases the

* We lately met with a case exemplifying the effect of sudden change of temperature. A person who had been treading snow in an ice-house felt his feet uncommonly cold. To remedy this, he plunged them into water somewhat heated. The consequence was, the little toe of one foot and part of the great toe of the other mortified, and had to be cut off.

198. Define the rete mucosum, and the cutis.
199. Importance of the skin and its functions.
200. Illustrations of the mischiefs of sudden change of temperature.

effect seems to be produced principally through the agency of the nervous system, for an account of which we must refer to Section VIII.; but when the application of cold produces its injurious effects, the blood that is forced, by the constricted vessels, from the surface, upon the internal parts, probably also overloads them, and impedes the due performance of their functions. When the body is exposed for some time to a great degree of cold, the tendency to sleep becomes almost irresistible. Under these circumstances, to use the words of Dr. Solander, quoted by Captain Cook, "whoever sits down will sleep, and whoever sleeps will wake no more." These words were used by Dr. Solander during an excursion in Terra del Fuego, with Sir Joseph Banks and nine other individuals, when the cold was intense. Notwithstanding Dr. Solander gave the precaution, he was the first to feel the effects of the cold, and his companions were obliged to yield so far to his entreaties as to allow him to sleep for five minutes. With the utmost difficulty he was roused. Two black servants also slept, and perished. Exposure to a lesser degree of cold acts differently. Every one knows the power of cold draughts of air, of cold or damp feet, the wearing of damp clothes, or sleeping in damp sheets, in giving rise to inflammations, even in persons whose surface has a vigorous circulation, and is therefore not easily chilled. When the circulation on the surface is languid, these causes act with tenfold force; and hence in all such constitutions it is of the utmost moment, 1st, that the skin should at all seasons be protected from sudden chills by warm (the best are flannel) coverings; and, 2dly, that sea-bathing, a generous diet, and all other means that give permanent vigour to the circulation, should be specially attended to. Under all circumstances, indeed, frequently cleansing the skin, by removing noxious excretions, and allowing the proper exercise of its functions, has a much more important influence on health than is generally imagined.

201. Effects of exposure to cold; illustrations.
202. Danger of applying heat to frozen parts.
203. Practical suggestions.

Good views of the lymphatic vessels will be found in Lizars's Coloured Plates, page 99, and of the skin, at page 82 of the same. Connected with the subject of the skin, the teacher may introduce some instructive lessons on the five varieties of the human species and their distribution. We have found that these lessons are rendered much more impressive by having drawings of these varieties, and also a skeleton map of the globe, of a large size (say six feet by four), coloured so as to indicate their different localities. Thus, the European, or Caucasian, may be left white, the Mongolian coloured yellow, the American red, the Malay brown, and the Ethiopian black. The drawings, and the requisite information as to localities in making this map, will be found in the latter part of Lawrence's Lectures on Man, 8vo edition.

SECTION VII.

LOCOMOTION—THE BONES, MUSCLES, &c.

122. Having now given a short account of the most important functions of the organic or vegetative life, we shall here consider shortly the parts that are immediately concerned in producing the motion of the body. These are the bones and their articulations (joints), and the muscles.

123. The most important of the hard parts in animals are shells, crusts, and bones. The two former, however, are void of vitality, while bone gives every indication of possessing life. In shells, almost no animal matter is found; they are nearly the same in composition as a piece of marble. Crusts (as the lobster's) have a larger proportion of animal matter; and in the composition of bones there is much more. Not only, however, is the earthy matter less in bones; it is also differently combined. In shells and crusts the earth is carbonate of lime (chalk), while in bones the lime is principally united with an acid composed of phosphorus and oxygen, forming phosphate of lime; and it may be remarked, that it is from bones that phosphorus is usually obtained.

124. The quantity of animal matter in different bones, and, consequently, their hardness, varies. In infancy and

204. Name the hard parts of animals.
205. Composition of these.

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204. Name the hard parts of animals.
205. Composition of these.

youth the animal matter predominates; in old age the earthy matter. On an average, perhaps, in mature age, about two-thirds are animal (mostly gelatin and albumen) and one-third earthy matter. Mere hardness, however, is not all that is wanted, for the hardest are often the most brittle substances. The composition of bone, therefore, is such, that the earthy matter may give stability to the framework, on which all the other parts are to hang and work, while the animal matter imparts to it adhesiveness and toughness.

125. It is found that all the parts which afterwards become osseous (bony) are originally in the state of cartilage or gristle; that this is gradually removed, and bone deposited in its stead; and that ultimately, in its highest state of development, the bone is hollowed out internally, and is filled with marrow, or, in birds, with air.* Some of our bones are completely ossified at birth, as is the case with the bones of the ear; most of the others become more or less so in a few years afterwards; but some parts continue cartilaginous even in manhood, and become perfectly ossified only in old age. This is the case with the cartilages that join the ribs to the breast-bone; and as the elasticity of the cartilage materially assists in breathing, it is easy to understand that the change is not an advantageous one.

126. Perhaps the most rudimentary form of an internal skeleton exists in the sepia, or cuttle-fish. It is merely a collection of bony plates, which gives support to its soft body, and forms a ring superiorly, through which part of its nervous system passes. The first object, in laying the foundation of the skeleton, appears to be to provide for the security of the brain and spinal marrow, as protection to these from injury, we shall afterwards find, is of the very highest importance. Accordingly, whatever other parts

* When thus hollowed, the bone is found to be much stronger than if the same amount of hard substance had been disposed in the solid form.

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206. Proportion of animal matter in bones.
207. Primitive state of bone in the formation of the body.
208. What bony structure is uniformly found?
209. The advantage of the bones being hollow.

of the skeleton are wanting, it has been already mentioned that the back-bone, or spine, is always present; and further, in the human race, and in all the other Vertebrata, this is invariably the first part of the osseous structure which nature developes.* It is composed of a series of rings or vertebræ, variously joined together in the different classes. Each side of a vertebra, in fishes, forms a cup, and, consequently, when the whole vertebræ are joined, two cups are always opposed to each other—the cavity left being filled by a thickish jelly. In reptiles, the junction is

* We may here mention, that the various organs of animals are quite different when first developed, from what they afterwards are in their perfect state. On this subject have, of late years, been made perhaps the most astonishing discoveries in modern science. It appears that the organs of the different beings, before they can attain to the rank assigned them in the animal scale, must first pass through many of the phases which the same organs assume in the classes beneath them. Thus, the whole body of man is at first little larger than a pin's head, and has the simple pulpy structure of the lowest zoophyte; the brain at first is wholly wanting, and is subsequently like a fish's, a reptile's, a bird's. About twenty-one weeks after its development, the human brain has a close resemblance to that of the Rodentia, (marmot, &c.)

The human heart also, as in animals low in the scale, is at first wanting; then it is like a fish's; and even at birth, we have already remarked that communications exist between the venous and arterial circuits, as in reptiles. In the same way, what afterwards become bones, are at first a mere jelly, like the bodies of the Radiata; subsequently they are gristly, like the skeleton of the Chondropterygii (shark, ray, &c.); and ultimately they pass through the different stages of ossification. The same happens with all the other organs. It has even been found that the human embryo, at one period of its growth, is furnished, like a fish, with gills.

The transformations of insects afford beautiful examples of the same law; and every one has observed that the frog, before it becomes a reptile, remains for some time as a tadpole in the lower class of fishes. It has then gills, and is indeed in every essential a fish.

These discoveries give a most satisfactory explanation of certain of the cases called monstrosities. For example, a person or quadruped born without posterior extremities, may be said, in regard to these, to have remained in the state of development represented by the Cetacea; a person with hare-lip or cleft pallet represents the condition, in these particulars, of the hare, birds, reptiles, &c.: and so on with the heart, brain, and other organs.

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210. Varieties in the vertebral structure.
211. Curious lessons of comparative anatomy, as in the note.

what is called, by mechanics, of the ball and socket kind—the ball of the one vertebra fitting into the socket of that above it. The surfaces of the vertebræ in the Mammalia are nearly flat, and between each, in man especially, there is placed a thick, tough, and highly elastic gristle, which is of great use in breaking the shocks that would otherwise be sustained in running, leaping, &c. The mode of articulation in the fish and reptile allows of much more extensive motion than that of the Mammalia; but some parts of the spine in the latter possess much greater capabilities of motion than others. Fig. 25 shows one of the lower vertebræ in man. *a* is the surface by which it is joined; *b* the ring through which the spinal marrow passes, which Mr. Earle has shown, is, in the various species, of a width proportionate to the extent of motion enjoyed by the part.

Fig. 25. A Vertebra.

127. The articulation of the spine with the skull, in the Mammalia, exhibits one of the most curiously artificial contrivances to be met with in the body. The object contemplated is to produce a hinge that will allow of two kinds of motion, namely, 1st, such a motion as takes place when we turn the head from side to side; and, 2dly, such a motion as we employ in nodding the head, or one backwards and forwards. The mechanism by which this object is attained is of a most admirable kind, but at the same time of a kind which does not readily admit of description. It involves a great regard for the protection of the spinal marrow at the top of the neck, this being perhaps the most vital portion of the whole body. Injury to it, or pressure upon it, is instantly fatal.

128. Taken as a whole, the human spine is a most curious and perfect piece of mechanical art. It combines the two apparently almost incompatible requisites of great

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212. Varieties in the vertebral structure.
213. Describe the human vertebra.
214. Wonderful union of the spine with the skull.

strength and sufficient flexibility. The flexibility is principally produced by the number of pieces employed, which are so firmly knit together, that dislocation of them without fracture, is a very rare case. Let any one, as Dr. Paley observes, try, by main force, to separate the vertebræ even of a hare or rabbit, and he will soon learn how firmly they are united.

129. The spine is surmounted by the cranium, or skull (see Fig. 7), which consists of a number of separate pieces joined together, forming a strong case for the brain, constructed on the principles of the arch. Connected with the skull are the organs of the principal senses and of mastication, which, amounting, in the large animals, to a considerable mass, render necessary various contrivances. In the bird, the head is at the end of a long neck, but the skull is made extremely light. The skull and bill of a common fowl are only about the weight of a sixpence. In the cow, camel, &c., the neck, from the food on which they live, is necessarily long, and the head is heavy; and hence there are powerful muscles, that are attached to the skull, and to long spines projecting from the back of the vertebræ of the neck, and an elastic rope, or ligament, fixed also to the same parts, that assists to raise or to support the head.* In the elephant the weight of the head is so enormous, that nature has had, besides these contrivances, to shorten the neck so much as to necessitate the formation of a proboscis, or trunk. One of these sagacious creatures died of a lingering disorder a few years ago in Paris. It was never seen to lie down till the day of its death, and, when very feeble, what seemed to give it the greatest distress, was the effort requisite to support its head.

130. The other parts of the skeleton are less essential. They are modified in numerous ways in different species to suit particular purposes, and some are occasionally wanting altogether.

* Vulgarly called pax-wax, or maiden's hair.

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215. How is strength and flexibility in the spine secured?
216. What is said of the skull in different animals?

131. The clavicle, or collar-bone (Fig. 7, *y*), is one which has obvious and interesting relations. This bone is perfect in man; it is imperfect in the tiger, &c.; and is wholly wanting in most of the herbivorous tribes. Now, what can be the reason for these differences? The reason is perceived from knowing the uses of the bone, for it is of service only where the upper extremities are much used in laying hold of objects, as in the monkey, squirrel, man, &c.; and to them it serves the important purpose of separating the limbs, and thus allowing sufficient extent of motion. Would it not, then, have been of service to the cow or the horse? Certainly not: quite the reverse. When, in running down a hill, we fall on our hands or shoulder, or stop ourselves with our hands against a wall, one of the most common accidents is dislocation or fracture of the collar-bone, because this bone is directly connected with the arm and breast-bone, and, of course, sustains a great part of the shock. But when a horse gallops down a hill, or leaps, the shock is greatly more violent, and yet no bone is broken. The reason of this is learnt by inspecting its skeleton, for we find that the fore-legs are not connected with the trunk by bones at all, but by two enormous fleshy muscles attached to the shoulder-blades (Fig. 7, between the situations of the letters *y* and *r*), between which the heavy body safely swings.

132. The breast-bone (Fig. 7, *x*) is almost rudimentary in fishes, as they have properly no chest, the gills and the heart being placed under the head. The same bone in birds is very large, to give an extensive surface on which the muscles that move the wings may be fixed. In the tortoise and turtle its size is enormous, forming a covering to the whole of the under part of the body.

133. The extremities are parts in which it is very interesting to trace the modifications which nature employs to fit the same bones for different uses. In Fig. 7 we see the human arm and hand, composed of the humerus, or princi-

217. What of the clavicle, and its presence or absence in different animals?

218. What of the breast-bone?

pal bone (*b*), the two bones of the fore-arm (radius and ulna, *d*, *e*), the bones of the wrist (*f*), and the fingers (*g*). Fig. 26 represents the paddle, or fin, of the porpoise, which might

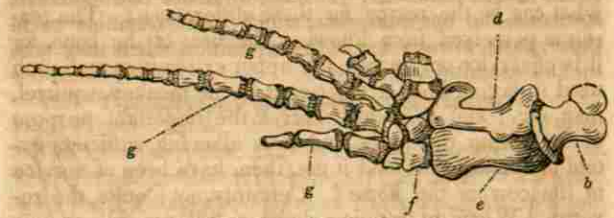


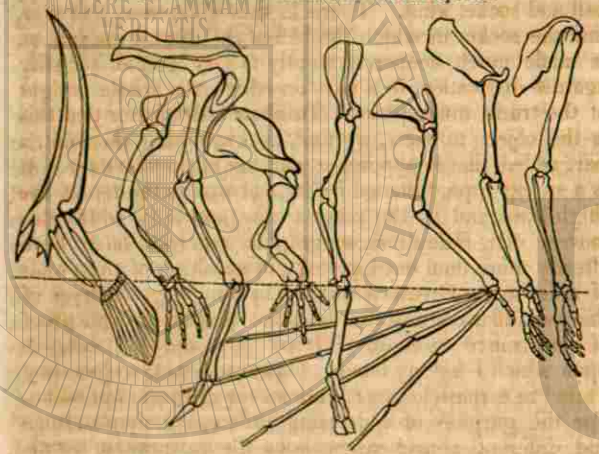
Fig. 26. Paddle, or fin, of the Porpoise.

almost be taken for some burlesque representation of the hand and arm of man. The parts are marked with the same letters, from which it will be seen that the humerus and bones of the fore-arm are short, flat, and strong, and that the joints of the fingers have been greatly increased to give extent of surface. Almost the whole body of the skate and of the ray-fish is composed of what represent the two hands, immensely expanded. In Fig. 27, taken from Dr. Fletcher's Rudiments of Physiology, the anterior extremities of different species are sketched, and a mere inspection will show at once the general resemblance of the parts and their modifications. As the extremities of the deer, horse, cow, &c., are formed for solidity, we find, in different parts, that there is only one solid piece for two, three, or more bones, in the corresponding parts of man, but even these solid pieces are found originally to have been several distinct bones, that have afterwards united. Of all the modifications which the different portions of the extremities undergo, the human hand is undoubtedly the most beautiful. Marks of the greatest care are everywhere visible in the formation of this most admirable structure; and whether we regard its fine sensibility, or the power, rapidity, and delicacy of its movements, we must acknowledge that no similar part in other animals can be compared with it. Its chief superiority, as an in-

219. Explain the diagrams.

strument of prehension, arises from the length, mobility, and strength of the thumb, which can act as an antagonist to all the other fingers, giving us something like the power of two hands conjoined. Indeed, we notice that monkeys, squirrels, the opossum, &c., which most resemble us in these parts, always use both extremities, when they take up and examine any object.

Fig. 27. Anterior Extremities of Various Species.



134. It is not possible, on the present occasion, to say more than a few words regarding the joints, although there are many things connected with them well worthy of attention. The bones forming joints are firmly knit together by parts called ligaments; the bones are covered with a smooth gristle at their extremities, that they may move easily on each other, and there is a kind of oil poured into the joint to assist this still further. We have various kinds of joints in the body. There is the hinge-joint at the

220. What of the modifications of the same bones in different animals.
221. What is wonderful in the human hand?
222. How are the joints constructed?

elbow, that admits of motion only backwards and forwards; the ball and socket joint at the shoulder, that allows of motion in every direction; as well as several other kinds. We shall only further observe, on this subject, that there is a part connected with the hip-joint which is worthy of particular notice. The bones of the lower extremity are constructed on the same plan as those of the upper, but are stronger; and the hip, like the shoulder-joint, is of the ball and socket kind. There is this difference, however, that the socket in which the ball of the thigh-bone moves, is made much deeper, evidently to give greater security against dislocation, in a part on which the whole weight of the trunk must press. To show still further that this is the object in view, we find, on examining the joint, a part added, that is altogether wanting at the shoulder. It is a strong rope, fastened by its one end to the top of the thigh-bone, and by the other to the socket in which this moves. Dr. Paley (whose graphic remarks have been already more than once quoted), in speaking of the proofs of a designing Creator exhibited in our body, observes of this part, that nothing can be more mechanical, no proof of contrivance stronger. "It is," says he, "an instance upon which I lay my hand. One single fact, weighed by a mind in earnest, leaves oftentimes the deepest impression. For the purpose of addressing different understandings and different apprehensions—for the purpose of sentiment—for the purpose of exciting admiration of the Creator's works, we diversify our views, we multiply our examples; but, for the purpose of strict argument, one clear instance is sufficient; and not only sufficient, but capable, perhaps, of generating a firmer assurance than what can arise from a divided attention."

135. Having got the solid skeleton, the agents employed in producing its motion are the muscles. By a muscle is meant a fleshy body, possessing the peculiar property of contractility, or of shortening itself. When we cut a piece of meat, it is the flesh we notice which is the muscular

223. Name some of the varieties.
224. Reflections of Dr. Paley.

part. When we move our fingers, and look at our fore-arm, we can see the muscles that move them contracting; or we can feel the muscles in strong contraction when we press a finger on each side of the cheeks, near the angles of the lower jaw, and firmly close the jaws; or when we place one finger in the armpit, and the other on the breast, and then draw the arm downwards and across the chest with a jerk. This contractile power of muscles is quite different from elasticity. The first is an original source of power, while elasticity merely modifies its distribution. Thus, it is the elasticity of the mainspring of a watch that keeps it going for twenty-four hours, but the muscles of the hand which winds it up is the true moving power.

136. The muscles are generally collected into bundles, which are found, when examined, to consist of lesser and lesser bundles, bound together by firm sheaths. Those employed for moving the skeleton are fixed by their ends to the bones, and are very various in their shapes, but commonly terminate in tendons, or sinews, which are of a very intricate structure, and of great strength. Taken together, the tendon may be viewed as a strong rope, and the muscular fibres, when contracting, as so many hands that are pulling at it. Fig. 28 shows the bundles of fibres of which a muscle is composed; Fig. 29, the zigzag state into which these are thrown during contraction, and which, indeed, is the cause of contraction.*


Fig. 28.


Fig. 29.

137. Professor Ehrenberg states, that even in animalcules, when these minute creatures are darting through the fluid, he has seen parts contracting which he thinks are muscular bands. The bodies of the other Radiata seem almost wholly contractile, but no distinct muscles have

* Prevost and Dumas, two eminent French physiologists, describe this as the appearance of the muscle when contracting, but the accuracy of their description has lately been rendered doubtful by other researches.

225. What is a muscle? and its use, properties, &c.?
226. Peculiarities of the muscles.

hitherto been discovered, and their powers of locomotion are generally very limited. Except in the highest of the Mollusca, the locomotive powers are not much greater; but many of these have distinct and strong muscles. It is by powerful muscles that the oyster and the mussel so firmly close their shells. The muscular system of the Articulata is particularly well marked, and their activity and power are proportionately great. Lyonet has counted, in some species of caterpillars, not less than 4000 muscular bands. A beetle, placed under an ordinary candlestick, is able to move it; a fact which shows a wonderful degree of muscular energy in so small an animal. Ants will carry loads forty or fifty times heavier than their own bodies; and a small insect, called the *Cicada spumaria*, will leap five or six feet—at least two hundred and fifty times its own length. Dr. Roget remarks, that this, if the same proportions were observed, is equal to a man of ordinary stature vaulting through the air a quarter of a mile.

138. It is, however, in the vertebrated division that the action and arrangement of the muscular system have been studied with the greatest care. Anatomists have given names to between 400 and 500 muscles in the human body; but the parts of what is called a single muscle by anatomists, often have different and even opposite uses. Professor Grant states, that, in the proboscis of the elephant alone, there are nearly 1000 muscles.

139. The covering of the skin hides from our view the busy scene beneath. Could we behold properly the muscular fibres in operation, nothing, as a mere mechanical exhibition, can be conceived more superb than the intricate and combined actions that must take place during our most common movements. Look at a person running or leaping—or playing on a harp or piano—or watch the motions of the eye! How rapid, how delicate, how complicated, and yet how accurate, are the motions required! Think of the machinery necessary to articulate distinctly 400 words, most of them requiring several separate move-

227. Number and force of muscles illustrated.
228. Name some of the wonders of muscular action.

ments, in the space of a minute; or of the endurance of such a muscle as the heart, that can contract, with a force equal to sixty pounds, eighty times every minute, for eighty years together, without being tired.

140. To muscular contraction are principally owing the infinitely varying shades of expression in the human countenance; and even in the lower animals, we see that the feelings to be expressed, and the parts that are to express, are in unison. A cow or a horse not only does not snarl like a dog or a tiger, but is absolutely incapable of doing so; and for this plain reason, that the latter are furnished with express muscles for drawing up the sides of the mouth, which the cow and horse altogether want.

141. The muscles are generally arranged in sets, which are opposed to each other, like workmen in a saw-pit. We have thus a set that bends the limbs, and a set that extends them; sets that lower the body or head, and sets that raise them up; and it is even in the same manner that the mouth is kept in the centre of the face. When palsy affects the muscles on one side of the face, those opposite, having no counterbalancing power, draw the mouth to that side.

142. It is exceedingly interesting to note the many modes nature employs to accomplish progressive motion among the Vertebrata—making use of two legs in man, four in quadrupeds, the legs and tail in the kangaroo, the tail in fishes, &c. &c. We can say only a few words as to her greatest achievement in locomotion, that of flight—a feat which it has foiled all man's ingenuity to imitate. When an animal has to pass rapidly through the air, nature seems to have bestowed her chief care upon two circumstances; 1st, to lighten the whole fabric as much as possible, which is principally accomplished by making the solid parts thin and hollow, at the same time that the whole body is filled with air like a sponge. Thus, the skeleton of a pelican, five feet long, was found to weigh

229. Influence of the muscles on the face.
230. Symmetrical pairs of muscles, antagonists.
231. Differences in locomotion among animals, and corresponding structures.

only twenty-three ounces. And, 2dly, by concentrating the muscular power in those parts that are to be the chief instruments of motion. The two pectoral muscles which move the wings of the swallow, have been estimated to possess more power than all the others in the body put together. A flap from a swan's wing has been known to break a man's leg, and a similar blow from an eagle has been instantly fatal. This great power will appear absolutely indispensable, when we consider that a swallow, as well as many birds of prey, will probably often pass through not much less than 1000 miles daily. All the functions, indeed, contributing to locomotion, exist in the highest intensity in the bird. Its skeleton, of all animals, is the most highly ossified; its muscles act with the greatest energy; its blood, to support this energy, is richest in red globules, and the respiration, to arterialize the blood, in it alone is double.

143. Perhaps no ordinary circumstance has so much influence on the general health, as due attention to the state of the muscular system. We may be convinced of this in two ways; for, 1st, we see persons, whose system no means can prevent continually running into disorder, evidently because they persist in leading an indolent, inactive, or sedentary life, in which the exercise of the muscles is totally neglected; and, 2dly, we see others, who neglect almost all the rules considered essential for securing health except this, that they incessantly exercise their bodies in the open air, and who yet pass through life almost without a bodily ailment. Under ordinary circumstances, and with a moderately good constitution, in a country like our own, we may say, that the condition above all others which can secure and preserve the inestimable blessing, health, is varied exercise in the open air. With this, our food, however plain, is sweet, our body is light, our digestion easy. Without it, the salt that gives relish to every dish is absent—we live the prey of a thousand tormenting sensations—our diseases become

232. Importance of muscular action to health.
233. Practical suggestions, and results.

intractable, our secretions morbid, our children are weakly and stunted, and the term of life is materially shortened.

144. Among the poorer classes, those who suffer most from neglecting muscular exercise, are the various artisans who follow sedentary occupations, and females who are constantly employed in different kinds of needle-work, &c. Among the more wealthy classes, literary persons, and those engaged in engrossing occupations, suffer much

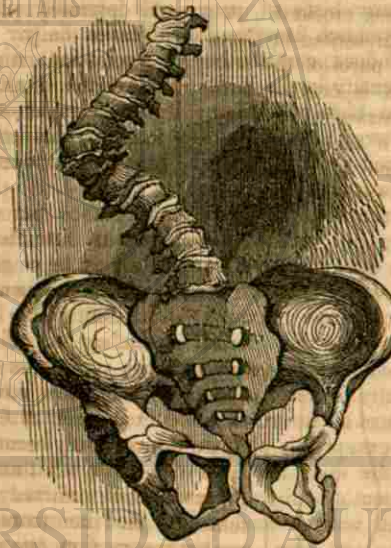


Fig. 30. Deformed Spine.

from neglect of it; but, above all, females suffer from this cause, and especially young females attending school, who are often at once enormously overtasked, in acquiring what are considered the necessary branches of education, and denied those playful sports, which alike nature and com-

234. What of sedentary employments?
235. Illustrations in the diagram.

mon sense dictate as agreeable and proper. In all the classes of persons referred to, the effects of neglected muscular exercise are shown in a general increased susceptibility to disease; and in the females of the better classes, inability of the muscles to support the spine, and consequent curvature of it, are but too common. Dr. Forbes states, that in a boarding-school, containing forty girls, which he inspected, he did not find one, who had been at the school for two years, whose spine was not more or less crooked. A greatly deformed spine of this kind is represented in Fig. 30. The spine (by which all the upper parts of the body are supported), it should be recollected, is composed of twenty-four pieces, that are kept in a straight position by the contraction of its muscles; and if these are not exercised, like all other parts, they become weak and shrivelled, and are thence unable to support their burden. In Fig. 31, A shows the natural upright line the spine presents when viewed from behind; B shows the deviation a girl's spine sustained after the muscles had been weakened by a fever, but which went nearly off in a few weeks from proper exercises; C shows the line the spine then presented; D shows a case in which this deformity had become inveterate. To show what an extent of injury is thus inflicted on young females, in the more wealthy ranks, we may mention, that the late Mr. Shaw, of London, who had great experience in this disease, states, that for one poor child twenty rich ones are affected; that among the poor children, the proportion of boys and girls is about equal; but that, among the rich, for one boy a hundred girls have crooked spines. It must be

Fig. 31. Deformities of Spine.

236. Dangers of young females at school.
237. Pernicious effects of neglected exercise.
238. Danger of tight lacing.

obvious, therefore, that there is something greatly wrong in the system of training to which these girls are generally subjected.*

145. We can but very briefly refer to the kinds of exercise that are most proper. These, indeed, must vary with the condition, the opportunities, and the inclinations of individuals. In general, when the weather permits, three or four at least out of the twenty-four hours should be spent in some out-of-door exercise. Let this be persevered in, and there are few who will not acknowledge its benefits. Such exercises as engage the mind at the same time are to be preferred. Games and sports, gardening, botanical and geological excursions, hunting and shooting, &c., are of this kind. Where it can be had, perhaps one of the best, for both sexes, is exercise on horseback; but of whatever kind it may be, let this be remembered by all, that if it is wished to possess health, and properly to enjoy life, a sufficient amount of muscular exercise must be taken. [The value of exercise for children and young people, especially females, cannot be too highly estimated. In every school the seats at the desks should be provided with backs, nor should the scholars ever occupy their seats more than one hour at a time. Moreover the active exercise of the muscles of the arms, chest and back, should be a part of school discipline everywhere, and required to be performed in concert several times during the day, especially after being seated at their desks for any length of time. The intervals of study should be frequent, and cannot be better employed than by marching and singing, as is practised in the primary schools of the N. Y. Public School Society with remarkably good effect.

* No doubt, want of exercise is the main cause of this, but the pernicious fashion of lacing tight the stays also contributes to produce distortion of the spine; for besides that this prevents the natural supports, the muscles, being exercised, it is a physiological law that all parts much pressed on become absorbed. Perhaps, also, something is due to the false taste that prevails among the higher classes, as to a certain delicacy of habit being necessary to gentility. Nothing can be more unnatural, or more injurious in its consequences.

239. Importance of out-door exercise.

Among the recreations of children, those which call for active muscular exertion should be encouraged. Jumping the rope is admirably adapted to girls, and will be found preferable to swinging, and greatly to be preferred to dancing as an exercise, irrespective of the unhealthful and demoralizing associations usually concomitant with the latter.

But by far the most salutary and invigorating mode of exercise for young people is found in the cold plunging or shower bath, to which children should be trained by their parents, as a part of domestic discipline. The utility of this practice cannot be overrated.]

146. There is one state of the bones called rickets, in which the earthy matter is deficient, and which often proceeds from original weakness of constitution. The bones are consequently soft and yielding, and are sometimes bent in a most extraordinary way. There is another state, in which the amount of earthy matter in the bones is too great, and then they are very brittle. This happens generally in old and in young people. We lately saw a girl whose thigh-bone broke from merely turning in bed. Dr. Good saw an old lady who broke both her thigh-bones merely from kneeling in church, and who had her arm broken on being lifted up.

147. The bones, joints, and muscles, are all subject to various other diseases. In scrofulous habits, the bones and joints are particularly liable to low, obstinate affections, which wear out the constitution, and often render necessary the removal of the limbs. Rheumatism is a particular kind of inflammation that attacks the joints or muscles, and which occasionally becomes excessively dangerous, from leaving these and attacking the valves of the heart, and the bag (pericardium) in which it is contained.

To show the animal without the earthy matter of bones, steep the rib of a sheep, or other slender bone, in one part of muriatic acid (spirit of salt), and eight of water, for a few hours. It will then bend

240. What of different modes of exercise?
241. Diseases of bones and joints.

in any direction. To show the earthy without the animal matter, place a bone in a clear fire for about ten minutes.

A vertebra or two of the horse or other quadrupeds should be seen, to form a proper idea of the spinal canal, &c.; and also the back-bone of a cod or haddock. A section of a cod's spine should be made to show the cup-like cavities in the bodies of the vertebræ. The articulations of the two upper vertebræ referred to in the text, can be well seen in the calf. Give the butcher directions to preserve attached to the head the two upper vertebræ; clear off the flesh from the fore part of these, cut into the first and second articulations, and separate the vertebræ from the head. The tooth-like process, the ligaments, &c., will then be seen. At the same time may be shown the ligament that supports the head, by cutting away the flesh behind the vertebræ.

To give a clear idea of what a muscle is, it is interesting to take off the skin from a pigeon's breast, and show the extent of its immense pectoral muscle. On the other side, the muscle may be cut through to show its thickness; and its attachment to the first bone of the wing (humerus) should be shown. A small muscle (lesser pectoral), having a different insertion, will be found beneath the greater pectoral. The comparatively small size of the muscles of the leg, the tendons going to the toes, &c., may also be easily shown.

A stucco cast, showing the superficial muscles of the human body, may also be made very interesting, when their uses can be explained.

The inspection of a few skeletons or parts of skeletons of any of our common animals—a dog, cat, squirrel, weasel, mole, cock, swan, cod, &c.—adds greatly to the interest of this section; and it is still better, where there is an opportunity, to visit such collections as the Anatomical Museum belonging to the University or Royal College of Surgeons in Edinburgh.

For appropriate figures to illustrate this section, see Penny Cyclopædia, vol. viii., page 57;* Roget's Bridgewater Treatise, vol. i., pages 129, 178, 333, 337, 411, 437, 441, 447, 465, 530, 559; Bell on the Hand; Dr. Smith's Philosophy of Health, vol. i., pages 171, 189, 196, 205, 237, 312, 321; Bell's Anatomy, vol. i., pages 254, 258.

SECTION VIII.

THE NERVOUS SYSTEM.

148. We have now to enter on the consideration of those parts that essentially distinguish an animal from a vegetable, and the organs of the animal from those belonging

* A figure taken from the London Fashions answers better than the "modern beauty."

242. What essentially distinguishes animals from plants?

to the organic life; or, in other words, we have to speak of the parts that give us the power of voluntary motion, and which enable us to feel and to think.

149. In all but the most simple animals, it is quite certain that sensation and voluntary motion depend on the nervous system. The nervous system of man consists of the brain, the spinal marrow, and the nerves. As these are all composed of nearly the same kind of substance, we may view the spinal marrow and brain as nervous matter collected into masses, and the nerves as the same matter diffused over every part of the body. The brain, as has already been mentioned, is contained in and protected by the cranium or skull. It is also enclosed in three layers of fine membrane, the outermost of which (dura mater) is strong and tough, and adheres to the skull at different points; the middle layer (arachnoid) is so fine as scarcely to be visible; and the innermost one (pia mater) not only envelopes the brain, but also penetrates into certain parts in its interior. The spinal marrow has similar coverings, and is contained in the canal formed by the rings of the united vertebræ, represented in Fig. 25, *b*. The nerves are cords, attached to the brain and spinal marrow, which are composed of brainy matter enclosed in numerous minute sheaths, bound together by a strong covering (neurilema), as seen in Fig. 36, *g*.

150. When we examine the outer surface of the brain, we observe it folded or convoluted, as seen in Fig. 32, *a a a* (which shows a longitudinal section of the brain and upper part of the spinal marrow, with the nerves attached to them); and when it is cut into, we find it composed, 1st, of a gray pulpy substance, mostly placed externally, and, 2dly, of a similar white substance, placed internally. The same materials exist in the spinal marrow, but the white matter is external, while the gray is internal. What is commonly called the brain, is divided by anatomists into the cerebrum or proper brain (Figs. 32, *a*, and 33, *a*), and the cerebellum or lesser brain (Figs. 32, *b*, and 33, *b*),

243. Describe the nervous system.
244. What is said of the brain and its membranes?
245. Difference externally and internally in colour.

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244. What is said of the brain and its membranes?
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which presents in its interior the branched appearance of a tree (arbor vitæ), as may be observed in Fig. 32. Both these parts are divided longitudinally into two halves or hemispheres, and also transversely into lesser parts called

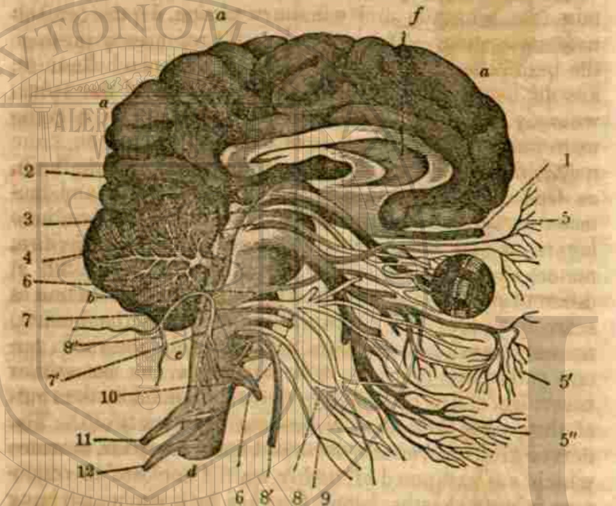

Fig. 32. Side View of the Human Brain.

Longitudinal section of the cerebrum, cerebellum, and medulla oblongata. *a a a*, the cerebrum. *b*, the cerebellum. *c*, the medulla oblongata. *d*, the spinal marrow. *f*, the lateral ventricle. 1, the olfactory nerve. 2, the optic nerve. 3, 4, 5, 6, the 3d, 4th, 5th, and 6th nerves. 7, the portio dura of the 7th nerve. 7′, the auditory nerve. 8, the glossopharyngeal nerve. 8′, the par vagum. 8″, the spinal accessory nerve. 9, the hypoglossal nerve. 10, the suboccipital nerve. 11, 12, spinal nerves.*

* The functions of the different nerves, which will immediately be adverted to, may be made plain by having a large drawing of Fig. 32, so coloured as to distinguish each kind; or, what will answer equally well, perhaps, the pupil can colour the nerves in the cut. The following may be placed beneath the drawing:—

NERVES OF SENSATION (coloured red). No. 1, olfactory—No. 2, optic—No. 5, 5′, branches of the 5th nerve—7′ auditory nerve.

NERVES OF MOTION (coloured blue). Nos. 3, 4, 6, go to the mus-

246. Describe and explain the diagram.

lobes. The connections of the two are clearly seen in Fig. 35, in which the convolutions are supposed to be unfolded, and the parts separated. *a a* is the cerebrum, *b b* the cerebellum. Fig. 33 represents the base of the brain (*a*) and cerebellum (*b*), the anterior surface of the spinal marrow (*c*), and the nerves going off from these.

151. In the interior of the brain there are several cavities called ventricles, two of which are of considerable size. Into these cavities, one of which is seen in Fig. 32, *f*, there is continually poured out a clear fluid, which, in the healthy state, is immediately absorbed; but in a diseased state, this sometimes accumulates until it amounts to gallons, forming one variety of the disease called hydrocephalus, or water in the head. There are also other parts found in the brain, which have received names from anatomists, some of which will be noticed afterwards.

152. The spinal marrow is found to be composed of six columns, as represented in Fig. 36. Two are anterior, two lateral, and two pos-

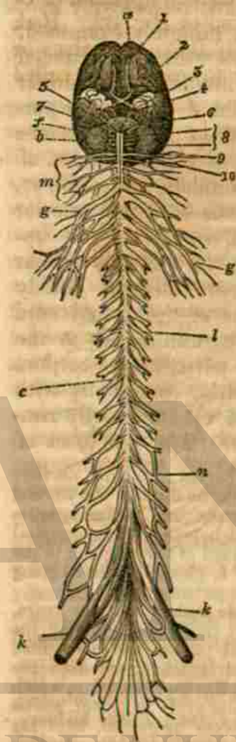

Fig. 33. Base of the Brain and Spinal Cord.*

cles of the eye—No. 7 (portio dura) goes to the sides of the head and face—8″, the spinal accessory nerve, goes to the muscles of the shoulder—9, goes to the muscles of the tongue.

NERVES BOTH OF SENSATION AND MOTION, OR MIXED NERVES (coloured brown). 5″, the lowest branch of the 5th nerve (the brown colour to commence where the upper branch of 7 crosses it)—10, 11, 12, and all below this.

DOUBTFUL NERVES (coloured black). 8, the glossopharyngeal—8′, the par vagum.

* View of the base of the brain, anterior part of the spinal marrow, and attached nerves. *a*, Cerebrum; *b*, cerebellum; *c*, spinal mar-

terior: in the cut, one of each is marked respectively *a*, *b*, and *c*. These columns, again, when minutely examined, are found to consist of bundles of fibres,* that can be traced upwards into, and are found to be continuous with, similar fibres composing the brain and cerebellum. The upper portion of the spinal marrow (Figs. 32, *c*, 33, *f*), which receives the name of the medulla oblongata, is composed, 1st, of two parts called the corpora pyramidalia (Fig. 35, *e*), which appear to be chiefly continuous with the anterior columns of the spinal cord (Fig. 36, *a*), and to run upwards to the cerebrum (Fig. 35, *a*); 2dly, of two similar parts (Fig. 35, *ff*), called the corpora oliveria, chiefly continuous with the lateral columns of the spinal cord (Fig. 36, *b*), and likewise principally running up to the cerebrum; and, 3dly, of two other parts, called corpora restiformia, behind the corpora olivaria, continuous with the posterior spinal columns (Fig. 36, *c*), and chiefly running to the cerebellum (Fig. 35, *b*).† The two lobes of

row; *f*, medulla oblongata. 1, Olfactory nerves; 2, optic nerves; 3, 4, 5, 6, 3d, 4th, 5th, and 6th nerves; 7, portio dura of the 7th and auditory nerves; 8, glossopharyngeal nerves and pneumogastric nerves; 9, spinal accessory and hypoglossal nerves; 10, suboccipital nerves; *m*, cervical plexus of nerves; *g*, plexus of nerves going to the arms; *l*, dorsal nerves; *n*, lumbar nerves; *k*, plexus of nerves going to the lower extremities.

* The interesting discovery has been made within these few years, by German anatomists, that these fibres, and all the fibres composing the nervous matter, are tubes filled with a fluid. The annexed sketch (taken from the British and Foreign Medical Review, No. 12, in which a detailed account of this discovery is given), shows the fibres of one of the nerves magnified, with the fluid contained in them escaping from their extremities. It is probable that this discovery may be the means of throwing some light upon the functions of this hitherto little understood part of the animal frame.


Fig. 34.

† Sir C. Bell has described another part, which he calls the respiratory column, but it has not been generally admitted by physiologists. On separating the two corpora pyramidalia, the fibres can be seen very distinctly to cross from the right and left sides, and this is thought

247. Anatomical divisions of the brain.
248. What cavities are in the brain?
249. Describe the spinal marrow and its columns.
250. Name of the upper portion of the spinal marrow.
251. How is this divided?

the cerebellum are also connected with each other by a part (Fig. 35, *g*), called the bridge of Varolius.

153. These descriptions are necessary to make intelligible the functions of the different parts of the nervous system. We shall now state a few of these. When the spinal marrow is divided in the loins, sensation and all power of voluntary motion are immediately lost in the lower extremities; when the spinal cord is divided above where the nerves (Fig. 33, *g*) come off to the arms, the latter, and all the parts below, suffer in the same manner, but the animal can still breathe; when the medulla oblongata (Figs. 33, *f*, and 32, *c*) is divided or injured, respiration immediately ceases, and death of course is instantaneous. If, again, the division is made above the medulla oblongata, and below the bridge of Varolius (Fig. 35, *g*), respiration continues, and the animal may live for a longer or shorter time. Chossat, a French physiologist, who performed some experiments of the latter kind on dogs, thinks they die from an inability to keep up their natural temperature. Tortoises, however, in which the brain has been taken out, have lived for four or six months afterwards. The brain of a young puppy was removed, and it not only continued to breathe, but also sucked, when applied to the teat, or when the finger, moistened with sugar, was put in its mouth. There have also been many cases of children born almost wholly without nervous matter, above the medulla oblongata, which yet have lived and thriven for days, or even for several months.

154. The parts above the medulla oblongata, viz., the cerebrum and cerebellum, are generally considered as the especial seat of intellect and moral feeling. Upon the different functions supposed to be performed by different parts of these, is founded the modern science of phrenology. They are thought to be no further necessary to sensation

to be the reason why palsy, from injury or disease of the one hemisphere of the brain, frequently affects the opposite side of the body.

252. Effect of injury to the spinal marrow at the loins, at its upper portion, and at the medulla oblongata.
253. Curious cases of the absence of the brain.
254. What of the phrenological doctrine?

and voluntary motion, than as receptacles to treasure up the one, and an organ to direct the other. The brain itself is not possessed of sensibility, for when the skull has been fractured, and the brain has protruded, part of it has been repeatedly shaved off, without occasioning the least pain, and, in some of the lower animals, the whole of the upper nervous mass has been cut away, without the animal manifesting any uneasiness, until the instrument came close to the medulla oblongata. Cases of disease of the brain have been recorded which lead to the same conclusion. Dr. Abercromby mentions having seen a lady who died suddenly without almost a single symptom, and who was so well the evening before death, as to have been at a dancing party, one half of whose brain was ascertained, after death, to have been completely destroyed.

155. M. Magendie has made some curious discoveries connected with the effects of lesions of the parts situated above the medulla oblongata. When parts situated in the ventricles (corpora striata) are cut, the animal immediately darts forward and runs with rapidity. This phenomenon, he says, is particularly remarkable in young rabbits, the animal appearing to be impelled forward by a power within, which it cannot resist. It is a curious fact connected with this observation, that horses are subject to a disease that produces similar effects. The diseased animal easily goes forward, and will even trot or gallop quickly, but seems incapable of going backwards, and appears to have difficulty in arresting its progressive motion. On the other hand, when the cerebellum or medulla oblongata was injured in a certain manner, the tendency always was to move backwards. Some pigeons which had been thus injured, constantly moved backwards in walking for more than a month, and even flew backwards when thrown into the air. Another singular movement took place when the parts leading from the spinal cord up to the cerebellum (crura cerebelli), Fig. 35, *c*, were cut. When the one on the right is cut, a whirling motion takes place on that side, and sometimes with such rapidity that sixty turns are

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255. Experiments of Magendie.

made in a minute. M. Magendie says he has seen this continue for eight days, without stopping, to speak properly, for a single instant. When the opposite crus cerebelli is cut, rotation takes place on the opposite side; and

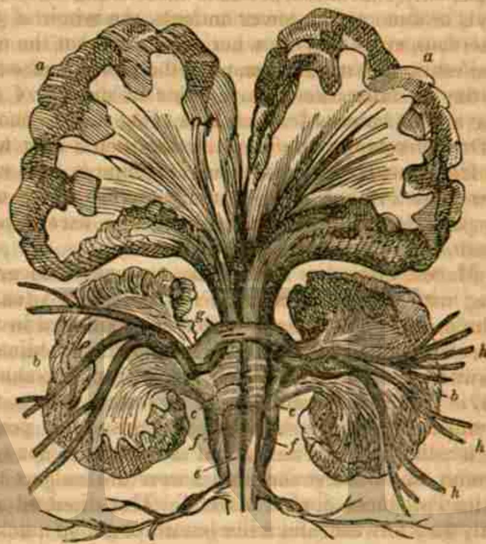

Fig. 35. Connection of the Cerebrum and Cerebellum.

when both are cut, motion in both directions ceases. Probably some disease of these parts existed in an insane person who was some years ago confined in one of the Edinburgh asylums, and who incessantly occupied himself in turning round in one direction. He might be stopped, or forced to turn in an opposite direction, but when left to himself, immediately turned as before.

156. We are indebted to Sir Charles Bell, however, for perhaps the most brilliant discovery ever made connected with the functions of the nervous system. We refer to

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256. What of Sir C. Bell's discoveries?
257. Distinction between sensation and power of motion illustrated.

his discovery of the different parts upon which motion and sensation depend. This distinguished physiologist was led to his investigations partly from considering the distribution of certain nerves, and partly from cases in which a person wholly loses the power to move a part of the body, and yet retains perfect sensation in it, or where the reverse of this happens—that is, where the power of motion remains while sensation is gone. Of such cases, the following may be taken as an example:—Francisco Cæsario, living in Rio Janeiro, fell from a scaffold twenty feet high. On recovering from the shock, it was found that his left side, from the shoulder downwards, was deprived of all power of motion, but that sensation remained in it; whereas, on the right side, his powers of motion were perfect, but sensation was then and afterwards so completely gone, that a lancet might be thrust deep into the flesh without giving him the slightest pain. From the middle of the neck upwards, motion and sensation on both sides were uninjured, and the line of demarcation was so exactly drawn, that it might be defined by a pack-thread surrounding the neck.

157. Now, of such cases as the above, Sir Charles Bell's experiments afford a most satisfactory explanation; for though a limb is deprived both of the power of motion and sensation by dividing the spinal nerves that go to it, Sir Charles Bell showed, that by tracing these nerves to their origin, they are each found to be composed of two parts,

Fig. 36. Section of Spinal Marrow.

one of which comes from the anterior column of the spinal cord (Fig 36, *a*), while the other comes from the posterior

258. What of the nerves from the anterior and posterior columns of the spine?
259. Explain the diagram.

column *c*, and, as represented, has always a small ganglion or swelling on it. He further showed, that if the anterior root *d*, be cut, the power of motion in the part supplied by the nerve is extinguished, as is also sensation, by dividing its posterior root *e*. In his experiments, when the posterior or sensitive roots of the nerves in a newly killed animal were irritated with a sharp instrument, no effect was produced; but when the anterior or motive roots were irritated, the parts of the body to which these nerves went, were thrown into convulsions. An ass was killed, and immediately the motive nerve which supplies the muscles of the jaw was irritated. The muscles contracted strongly, and closed the jaw with a snap; but when the same nerve was divided in a living animal, the jaw fell relaxed.

158. These explanations will render intelligible the account we shall now give of the functions of the different nerves derived from the brain and spinal cord.* They come off in pairs, as represented in Fig. 33. Fig. 32 shows, as already mentioned, a longitudinal section of the brain and medulla oblongata. No. 1 (in both Figures) is the first or olfactory nerve, which goes to the nose, and gives the sense of smell; and No. 2 (also seen in both figures) is the 2d or optic nerve, that goes to the eye, and gives the power of vision, both of which will be considered when we come to speak of the senses.

No. 3 (seen in both Figures) is a nerve that goes exclusively to the muscles of the eye. It has its origin from the anterior column of the spinal cord, which runs up to the cerebrum, and is, therefore, only a nerve of motion.

No. 4 (seen in both Figures) is the smallest nerve in the body, being, in man, little thicker than a sewing thread. It goes to a single muscle which moves the eye (trochleator); it is a nerve of motion, and probably has an origin similar to the last, though this has not been distinctly shown.

* The derivation of the nerves from the brain is considered only apparent, many physiologists believing that they can be traced to the spinal cord, as may be partly seen in Fig. 32.

260. What of the nerves, their origin and function?

No. 5 (seen in Fig. 33, but best in Fig. 32 and in Fig. 35, *h*) is a most extensive and important nerve. It is the highest that arises by double roots, and is, as shown by Sir C. Bell, both a motor and a sensitive nerve. Its first branch (Fig. 32, 5), which goes to the eye, eyebrows, forehead, &c., comes only from the posterior or sensitive root, and gives to the parts mentioned the sense of touch or common sensation. If this nerve were destroyed, we might have sensations from light, but we could have no feeling when any thing else came in contact with the eye. The second branch (Fig. 32, 5′), like the first, comes from the posterior root, and gives sensibility to the upper jaw, palate, upper lip, &c. The third branch (Fig. 32, 5″) has its origin from both the motor and sensitive roots, and hence gives both sensibility and the power of motion. It goes to the muscles, skin, &c., connected with the lower jaw, tongue, and mouth. The sensitive branches of the 5th nerve are those that are so painfully affected in toothache and tic doloureux.

No. 6 (Figs. 32 and 33) is the 6th nerve. It has only one root from the anterior part of the spinal cord, and is hence exclusively a motor nerve. It goes to a single muscle of the eye.

No. 7 (Figs. 32 and 33) is the motor, or hard portion, as it is sometimes called (portio dura), of the 7th nerve. It is extensively distributed to the muscles of the face and forehead. When it is cut, the muscles on that side are paralysed, and the mouth, as formerly noticed, is drawn to the other side.

No. 7′ (Fig. 32) is called the soft portion of the 7th nerve. It goes to the internal ear, and is the nerve of hearing.

No. 8 (Figs. 32 33) is called the glossopharyngeal nerve, from being distributed to the root of the tongue and pharynx. The functions of this nerve are at present the subject of dispute. It is considered by some physiologists as a motor nerve, by others as motor and sensiferous, while Panizza, a continental physiologist, contends, that from it is derived exclusively the sense of taste, and adduces

261. Distribution of nerves, and office.

several experiments which he thinks conclusive on this point. According to his view, this nerve gives the sense of taste, while the third branch of the 5th nerve (5″ Fig. 32) gives only common sensation or touch to the mouth and tongue, although physiologists have hitherto generally thought common sensation and taste might both be derived from this branch of the 5th nerve. Taste, according to the latter view, is considered a mere modification of touch. Professor Reid of St. Andrews, one of the most accurate experimenters on the functions of this and the two following nerves, is of opinion that the glossopharyngeal is certainly a nerve of common sensation, and that, although it may be concerned in giving us sensations of taste, Panizza is mistaken in supposing that taste is destroyed when this nerve is cut. Dr. Reid has also shown that this nerve is concerned in the motions of deglutition. Its motor power, however, is different from that of the ordinary motor nerves. When an ordinary motor nerve is cut, it is the part connected with the muscles it supplies which causes contraction in these, when its extremity is irritated, whereas, when the glossopharyngeal is cut, it is *the extremity connected with the brain* which excites muscular contractions in the throat when it is irritated. Physiologists have therefore latterly called this a *reflex* motion, or one which takes place probably by first producing an impression on the brain or spinal marrow. The proper motor nerves in this case are the branches of the next or pneumogastric nerves. The subject of reflex nervous action is at present exciting much interest among physiologists.

No. 8′ (Figs. 32 and 33) are called the pneumogastric nerves, from being distributed principally to the lungs and stomach. These are large nerves that run behind the carotid arteries in the neck. Although they have been very frequently experimented on, their functions are still a subject of dispute. There seems no doubt that they give motor branches to the top of the windpipe, the pharynx, the œsophagus, and probably also to the lungs, and they also seem to furnish us with some of the sensations from the lungs. Whe-

262. Describe the peculiarities cited.
263. Experiments of cutting nerves, and results.

the pneumogastric nerves are cut below the branches to the windpipe, the effect is, as formerly mentioned, generally, though not uniformly, to suspend the process of digestion, the food remaining in the stomach nearly unaltered. It was to these nerves that Dr. Philip, under these circumstances, applied galvanism, and found that the power of digestion was then restored.

No. 8″ (Fig. 32) is called the spinal accessory, and is considered to be a motor nerve. It is distributed to the muscles of the neck and shoulder. This is called by some anatomists the third branch of the 8th pair, the glossopharyngeal and pneumogastric being considered its first and second branches. The next or hypoglossal nerves, in this way, come to be called the 9th pair.

No. 9 (Figs. 32 and 33) is a nerve of motion, called the hypoglossal, from going to the muscles, and consequently producing the movements of the tongue.

No. 10 (Figs. 32 and 33) is called the suboccipital nerve, from coming out immediately below the occiput or back of the head. It goes to the back of the neck, &c., and belongs to the strictly regular nerves, or those which have both sensiferous and motor roots. All the spinal nerves below this, as seen in Figs. 32 and 33, also have sensitive and motor roots. They become interwoven in their course, forming, in different parts, what is called a plexus. The principal of these are, 1st, the cervical plexus (Fig. 33, *m*), which gives off, among others, two important nerves, one of which goes to the diaphragm, and is called the phrenic or internal respiratory nerve, and the other, from being also concerned in respiration, is called by Sir Charles Bell the external respiratory nerve. *g*, Fig. 33, is called the brachial plexus, from supplying nerves to the arm. Below this are the dorsal nerves (*l*), the lumbar nerves (*n*), and the sacral plexus (*k*), which last furnishes the large nerves that go to the lower extremity.*

* We have spoken of the nerves enumerated, as merely motor and sensiferous. Sir C. Bell thinks, however, that the motor power conferred is not the same in all. He contends that the 4th nerve (4), the portio dura of the 7th (7), the glossopharyngeal (8), the pneumogastric (8′), the spinal accessory (8″), and the external and internal respiratory, that arise from the cervical plexus (*m*), all come off from one tract of the spinal cord, which presides only over instinctive actions, such as respiration, acts caused by emotions, &c. Although Sir C. Bell's system has been supported with great ingenuity, its correctness in many points is not admitted by a large portion of both British and Continental physiologists. For much interesting information on this subject, see the works of Sir C. Bell, Dr. Marshall Hall, Dr. Fletcher, Dr. Reid in Edinburgh Medical Journal for 1838—39, &c.

264. What of the roots of nerves?

159. Besides the nerves described above, there is a most extensive system of nerves called ganglionic (from small gangalia or swellings with which they are connected), that are principally distributed to the lungs, bowels, and other viscera. Their functions are not precisely ascertained, but they do not confer either sensibility or the power of voluntary motion. They are generally supposed to be chiefly connected with secretion, and, from their connections with the spinal nerves, to form a bond of union between the rest of the nervous system.*

160. By whatever parts effected, there can be no doubt that a union or sympathy of the different organs does exist. The effects, in paralysing the heart's action, of a blow on the region of the stomach, of extensive burns, &c., have already been stated. If the brain of a rabbit be merely removed, the heart may beat for an hour or more afterwards, but suddenly crushing the brain instantly stops its action. Tickling of the soles of the feet, causing the action of the diaphragm that takes place in laughing, tickling of the throat causing vomiting, &c., are examples of a similar connection.

161. A subject of the utmost interest to the physiologist is presented in the modifications which the corresponding parts of the nervous system undergo in the different classes

* Some physiologists have thought that the functions of the ganglionic system are to confer on the muscles and other structures the property of irritability. The power the heart has of contracting when blood flows into it, is called its irritability. This opinion, however, is not generally admitted.

265. Define plexus, ganglion, and other technicals.
266. What is said of sympathy between remote parts?

of animals. In none of the lowest tribes of the Radiata have any traces of a nervous system been discovered, though these creatures seem to possess both feeling and voluntary powers. In the long round worm which infests the human intestines, a slender nervous filament passes along the lower part of the belly, and is divided by the gullet into two branches. The nervous filaments in the star-fish (Fig. 3) encircle the mouth, and radiate to its five divisions. In the Articulata the nervous cords are interrupted by knots or ganglia, which, it is probable, perform functions analogous to the brain and spinal marrow of the Vertebrata. The nervous system of the Mollusca contrasts with that of the Articulata, in assuming more of a circular form. In that of the sepia, there is a large ganglion, which is enclosed in something like a rudimentary cranium, and probably performs functions analogous to those of the brain. The parts from which the optic nerves are derived in this animal, are even larger than the part representing the brain.

162. In the vertebrated division, a brain and spinal marrow are always present, but the size of the parts composing the brain especially, is relatively so much altered, as almost to prevent them from being recognised. Among animals of this division, fishes have the most simple nervous system. From these there is a regular gradation in complexity of organization up to man, in whom all the parts belonging to the other classes are found, besides some that are peculiar to himself.

163. The nervous system of man is particularly distinguished by the ample development of the cerebral hemispheres. The human cerebrum extends so far backwards as to cover the whole of the cerebellum; the orang-outang's cerebrum allows the cerebellum to be seen behind it, and the otter's and sheep's do so still more decidedly. In the marmot, and other Rodentia, not only the cerebellum, but also the parts from which the optic nerves arise (optic tubercles, also called corpora quadrigemina), are partially exposed, and the convolutions on the surface of the brain

267. Varieties in nervous structure.

have disappeared. In birds the exposure is still greater, and becomes complete in reptiles and in fishes.

164. It was at one time thought that the brain of man was not only relatively, but absolutely, larger than that of any other animal; but it is now known that the amount of nervous matter in the elephant's brain, and in some others, is greater. Relatively, however, to the size of their bodies, the comparison is more in our favour. For example: in man, the ratio of the weight of the brain to that of the whole body is about 1 to 28, while in the dog it averages about 1 to 160, in the horse 1 to 400, and in the elephant 1 to 500. But again, on the other hand, it is curious to remark, that the brain of the canary bird, compared with its body, is as high as 1 to 14: and there is a species of monkey in which the proportion is even 1 to 11. For various reasons, however, comparisons of this kind are not considered as furnishing a fair estimate. Another method has been proposed by Soëmmering, an eminent physiologist, to which hitherto few if any exceptions have been found, and which depends on the ratio which the size of the brain holds to the aggregate bulk of the nerves that proceed from it. As an illustration of this method, the example of the horse may be cited. The absolute size of the brain of the horse is only about half that of the human brain, while the mass of the nerves of the horse, at their origin, is no less than ten times greater than that of man.

165. By adopting this principle, we are able, in most instances at least, to trace a correspondence between the cerebral development and the amount of intelligence, and we pass, by easy gradations, from one class of animals to another upwards to man, between whom and all the rest there exists a great gap. Between the two extremes the difference is very striking. To show this, we weighed a cod, and found it to be 27 pounds. We then weighed its brain (including all the nervous matter above the medulla

268. Differences in the form of the brain.
269. Proportion of brain in animals.
270. Relative proportion of brain and nerves.

oblongata), and found it to be 44 grains. As a comparison we weighed a child, which died four days after birth, and found it to be 7 pounds. Its brain was also weighed, and was found to be no less than 6912 grains. A similar comparison may be made with the adult brain. Mr. Scoresby found the brain of a young whale (whose body weighed 11,200 pounds) to be 3 pounds 12 ounces. The body of Byron or Cuvier would probably not weigh more than 200 pounds, and yet the brain of the former is said to have weighed 4½ pounds, while Cuvier's brain weighed 4 pounds 13½ ounces*—the heaviest we believe upon record.

166. From the great mass of nervous matter which man's brain contains, it is necessarily a very active organ. It is to it, as the organ of the mind, that we owe our pre-eminence as moral beings, as well as all that has been accomplished in the arts, in science, and in literature. While we cannot but be proud of what has thus been done, it must be confessed that the too great activity of this organ often leads to melancholy consequences. A large proportion of those who devote themselves to intellectual occupations, irreparably injure their health. This arises from two causes. 1st, Because these persons often do not mingle a due amount of bodily exercise with their studies. Many young students, especially, fall a sacrifice to this error. Where proper out-of-door exercise is regularly taken, we are inclined to believe that moderate study will in most instances be found the reverse of hurtful. But, 2dly, by far the most injurious consequences follow from such engagements or studies as continually excite, and agitate, and harass the mind, and consequently the brain. The constitution must be good, indeed, in which such a course does not give rise to impaired appetite, habitually painful digestion, or some more serious disease. The brain, like every other organ, if its powers are continually

* Brigham on the Influence of Mental Cultivation on the Brain.

271. Weight of the brain.
272. Effect of excessive activity of the brain.
273. Precautions suggested.

put upon the stretch, almost necessarily becomes itself deranged, or deranges some other organ.*

167. The diseases of the brain are too numerous to allow of even a reference to them individually. The one most commonly met with in practice, is perhaps that particular species of inflammation which gives rise to hydrocephalus, or water of the head. This fatal disease occurs most commonly in childhood, and the physician can usually trace it to the variety of constitution termed the scrofulous. The tendency to it is generally derived from parents: and hence, when it has once occurred or is suspected in a family, very great attention to the general health of the other members of it is called for. Another disease of the brain, unfortunately of frequent occurrence, is called delirium tremens. It arises from the continued use of ardent spirits. There are three organs especially affected by this baneful habit—the brain, the liver, and the kidneys. The two latter slowly, but surely, become diseased, and their diseases as certainly prove fatal. Delirium tremens, however, though a dangerous, is not usually a fatal disease. The person affected is in a high state of excitement, thinks he is surrounded by evil spirits, imagines all his friends are plotting against him, and a thousand other fancies. The mind, in certain other states and diseases, is also very singularly affected, which it would be curious to refer to, did our space permit. Dr. Abercromby's work on the intellectual powers, the works of phrenologists, those

* Every physician has melancholy experience of such cases. We lately met with a painful one, which may be mentioned as an example. A young gentleman, a student of divinity, of not a very strong constitution originally, met with a favourable opening for commencing a school in April, 1837. Anxious for the success of his school, as well as for the progress of his studies, he made the harassing duties of the former the only relaxation from the latter. The consequence was, as might have been naturally anticipated, that his health sank under it, and he was obliged to give up his school in April, 1838. His health continued in the most precarious state until June, 1838, when he was seized with inflammation of the membranes of the brain, which proved fatal. After death, not only the brain, but most of the other important organs were found in a highly diseased state.

274. Diseases of the brain.
275. What of delirium tremens?

on somnambulism and animal magnetism, &c., contain some very interesting facts on this subject.

To illustrate this section, the brain of a sheep should be exhibited, which can easily be done by sawing through the skull from behind the eyes down to the opening for the spinal marrow (taking care not to saw too deep), and then wrenching it off with a screw-driver or other strong lever. The membranes covering the brain will be observed. These should be slit open, and the brain lifted up anteriorly, when the different nerves, commencing with the olfactory, will come into view, and must be cut through, and the brain taken out and placed in spirits for a few hours to harden it. The nerves, as seen in Fig. 33, the ventricles in the interior of the brain, and the other parts described here, and in anatomical works, may then easily be seen. A cod's or haddock's brain and spinal marrow may easily be shown, by cutting with a strong pair of scissors the spinal rings and skull.

Besides these, if wished, the progressive development of the brain in different species may, with a little care and patience, be shown in the fowl, the hare or rabbit, the adder or frog, &c.

A few casts, showing the size and appearance of the human brain, that of the orang-outang, of idiots, &c., and casts of the heads of the Carib, Negro, European, &c., form excellent illustrations of this section, and can easily be got from O'Neil in Edinburgh, and other stucco dealers.

Appropriate figures for illustrating this section will be found in Fletcher's Rudiments of Physiology, Part 1, pages 47 and 48; in Lizars's coloured plates, pages 64, 67, 68; in Roget's Bridgewater Treatise, vol. ii. pages 547, 550, 552.

SECTION IX.

THE SENSES.

168. The senses are the means by which the mind becomes acquainted with external objects. Without the materials which they furnish, its exercise would be impossible. When the mind has once experienced various sensations, the memory can recall them when they are gone; the judgment can compare them, and can perceive their relations, and the imagination can combine them into endless varieties; but still, with all this, we are incapable of figuring to ourselves any image, the elements at least of which have not first been made known to us through sensation.

276. What of the senses, and sensation?

169. The senses generally enumerated are five, viz.: touch, taste, smell, hearing, and vision. There are other sensations, however, such as those of thirst, hunger, nausea, sneezing, &c., which cannot properly be classed under any of these heads.

170. The sense of *touch* is diffused over almost the whole external surface of the body, but is possessed in greatest delicacy by certain parts, such as the lips and the ends of the fingers. When the innermost layer of the skin is examined with a microscope, it presents numerous projecting points or papillæ, to each of which it is probable a branch of a sensitive nerve is sent, as they are seen in greatest numbers where the sense is most acute. To exercise this sense in perfection, it is requisite that the organ should be so constructed as to be capable of being readily applied to bodies, in a variety of directions; and it is in the human hand that this quality, the distribution of the sensitive nervous filaments, and a thin cuticle covering these, are united in the highest degree.

171. The late eminent Dr. Thomas Brown, professor of moral philosophy in Edinburgh, contended that touch gives us no, or at least very imperfect, ideas of extension or space, and of hardness or solidity. Our ideas of these, he thought, are principally derived from what he calls muscular sensations. Connected with this point, we may remark, that Francisco Cæsario, whose case has been before referred to, although entirely deprived of sensation on one side, so that even cutting it gave him no feeling, could yet, with the same, judge of the weight and consistence of bodies.

172. A similar conjecture, as to the feelings derived from temperature, seems to be supported by such cases as the following:—A physician of Geneva, after an attack of palsy, could be pricked or scratched in the right hand or arm, without giving him any sensation. When, however, he took a cold body into his hand, he felt it, but it

277. Name the senses, and other sensations.
278. What of touch?
279. Anomalous varieties of this sense.

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278. What of touch?
279. Anomalous varieties of this sense.

appeared to him lukewarm. Here the feelings of touch seem to have been lost, but a deranged perception of temperature existed.

173. The soft bodies of the lowest classes of animals are well fitted for the exercise of the sense of touch, and it is doubtful whether many of them possess any other. The organs of touch in insects, if, indeed, they are not allotted to some higher sense, are especially their antennæ or feelers, which, though in themselves minute, are generally feathered or radiated, so as to include parts too small for human vision, and the sensations of which must be of an exquisitely delicate nature. Huber, in his interesting work on bees, states, that it is by feeling with the antennæ that they seem to direct their various works in the interior of the hive. If an insect be deprived of its antennæ, it either remains motionless, or, if it attempts to fly, appears bewildered. A queen bee, thus mutilated, ran about, without apparent object, as if in a state of delirium.

174. Spallanzani discovered that bats could thread their way with ease through the darkest and most intricate passages, where obstacles had been purposely placed in their way, even when their eyes were put out or covered over, and hence thought that they must have some other sense to direct them. It has been rendered probable, however, that they owe this power to the delicacy of the sense of touch in their wings and other parts.

175. The senses of *taste* and *smell* may be spoken of together, as they appear in many cases to be intimately connected. The sense of taste resides in the tongue and mouth, and has generally been considered by physiologists as little more than a modification of touch. The 5th nerve was supposed to confer both touch and taste. Panizza, however, as was mentioned, has recently disputed this. The papillæ, already spoken of, are particularly well seen in the tongue. If a fluid, such as strong vinegar, be ap-

280. Peculiarities in the inferior animals.
281. What of bees and bats?
282. What two senses seem related to touch?
283. What of the papillæ?

plied with a hair pencil, they will be seen to become curiously elongated.

176. The tongue is covered with a thin cuticle, and the nostrils are lined by a soft membrane, called, from a celebrated anatomist, the Schneiderian membrane. It is upon this that the olfactory nerve (No. 1, Figs. 32 and 33) ramifies; not, however, covered by it, but protected from the air that passes through the nostrils merely by the natural secretion, called mucus. The vapour of different bodies thus comes directly into contact with these nerves.

177. Substances tasted must be either naturally fluid or must be dissolved by the saliva. When this condition is observed, we are sensible of certain feelings, commonly supposed to be produced in the mouth. A large proportion, however, of the feelings conveyed by the tongue, are little more than different degrees of pungency, which we may almost conceive capable of being felt by the ends of the fingers, had their cuticle been fine enough. The flavour of bodies, generally included when we speak of their taste, is a sensation entirely owing to the action of their vapour on the back part of the nostrils; so that, when the membrane that lines these is inflamed, or otherwise diseased, whisky, vinegar, mustard, and many other substances, can with some difficulty be distinguished from each other. Any one may easily satisfy himself of the indefinite nature of the sensation of taste, by pushing out the tongue, accurately closing the mouth and nostrils, and then applying to it different substances.

178. In the savage state, the sense of smell is much used, and becomes proportionately acute. The American Indians can easily distinguish different tribes and nations by the odour of their bodies. The blind and deaf boy, James Mitchell, whose history has been recorded by Mr. Wardrop and Professor Dugald Stewart, knew his friends, and at once detected strangers in a room, by this sense.

179. These senses are very acute in some of the lower animals, and particularly in the carnivorous Vertebrata.

284. Peculiarities of taste.
285. Acuteness of smell illustrated.

The olfactory nerves of most birds are small. In the duck and similar tribes, however, they are large, and are much used. The nostrils of fishes do not communicate with the mouth, and smell becomes with them more like taste, from the substance being dissolved in water instead of air.

180. The sense of *hearing* results from vibrations in an elastic substance, such as air or water, being communicated to the ear. When a bell is shaken in the exhausted receiver of an air-pump, no sound is heard, because the air which usually carries the vibrations to the ear is absent. Sound travels through air at the rate of about twelve and a half miles in a minute; through water its velocity is four or five times greater; and ice and other solid bodies are known to transmit it even more quickly.

181. The organ of hearing in man may be divided into external, middle, and internal parts. The external consist of the gristle of the ear (Fig. 37, *c*), of use in most animals for collecting the sounds; and of a funnel-shaped canal (*m*), which leads to the middle part or drum (*t*). The external and middle parts do not communicate directly, there being interposed between the two a thin membrane (*d*), attached to the bony sides of the canal, exactly like the parchment on a real drum. On this membrane the vibrations of the air strike, and to it

Fig. 37. The Ear.*

* *c*, concha or external gristle. *m*, canal leading to *t*, the tympanum or drum. *d*, membrane of the drum. *b*, small bones of the drum. *v*, vestibule. *s*, semi-circular canals. *k*, cochlea. *n*, auditory nerve. *e*, Eustachian tube.

286. Upon what does hearing depend?
287. Describe the diagram.

there is attached a chain of small bones (*b*), which are also connected with the internal ear, in which last is placed the nerve of hearing. The vibrations, therefore, first strike the membrane of the drum, and then pass along these bones to the auditory nerve, seen in Fig. 37, *n*. The cavity of the drum (*t*), though it does not communicate with the external ear, yet has air admitted to it. This passes through a canal (Fig. 37, *e*), called the Eustachian tube, which opens into the back part of the throat or pharynx. Most persons have felt their hearing become dull when inflammation of the throat closes this tube, and prevents the passage of the air. The internal ear is very intricate, and the uses of its different parts are not well known. In Fig. 37 are seen parts of it called semicircular canals (*s*), the cochlea (*k*), the vestibule (*v*), which are all filled with a fluid, and there is also seen the auditory nerve (*n*), going to these parts.

182. Of the parts described, it would seem that the internal ear is the only one that is essential, for cases have occurred in which disease has destroyed both the membrane of the drum and the small bones, and yet hearing has remained. It is a curious observation, made by Dr. Wollaston, that there are persons, of whom he himself was one, who are insensible to very acute sounds, though all others are perfectly heard. Some cannot hear the note of the bat or the chirp of the grasshopper, while others are insensible even to the chirping of the sparrow.

183. The Radiata, and almost all the Mollusca, appear to want this sense, but it is possessed acutely by many insects, though the organ used is not accurately known. In the sepia is found the simplest organ of hearing. It is merely a sac filled with fluid, with the nerve expanded in it, and having a hard body attached to its extremity. Fishes have this organ a little more complicated, but in neither these nor the sepia is there any external opening. They hear as we do when a hard body is held between the teeth, the conducting power of water for sound being

288. What connects the ear and throat.
289. Varieties in this sense and its organ.

much greater than that of air. When the Abbé Nollet sank his head under water and struck two stones together, the shock to the ear was almost insupportable. This organ becomes progressively more complicated in Reptiles, Birds, and the Mammalia. Among the last we first find external cartilages, which, as well as the internal tube, are directed forwards in those which pursue their prey, and backwards in timid animals, such as the hare, rabbit, &c.

184. The next and last sense we have to treat of is *vision*. All the affections of this sense are derived from the action of light. We think we see the bodies themselves that are scattered round us, but this is a mistake, for they themselves have no colour. The colour, or, more properly speaking, the power to produce the sensation we call colour, resides entirely in the rays of light that are thrown off or reflected from these bodies to our eyes. In spite of our convictions, however, we cannot help conceiving of our sensations as abiding qualities in these different objects.

185. If a ray of light be admitted through a small opening into a dark chamber, it appears white, but by causing it to pass through a three-sided piece of glass called a prism, it is seen to be composed of different coloured rays. These, according to Dr. Wollaston, are red, yellowish green, blue, and violet. In this way a ray of light is decomposed: when these colours are all uniformly blended, as when a card on which they are separately painted is rapidly whirled round, the resulting colour is again white. Now, it is from the power bodies possess of throwing off or of absorbing special rays out of the number, that they appear to us differently coloured. If a body appears blue, the blue rays alone have been reflected; and so on with red, green, and other colours. We do not notice any interval between looking at an object and the impression on our eye (as we can do with distant objects in the case of sound), from the rapidity with which light

290. What is said of vision?
291. What of light and its decomposition?
292. Relative velocity of light and sound.

travels, and from not having any other sense that can give us information more quickly. There is always an interval, however, and in the case of the distant heavenly bodies this has been calculated. We have said sound travels at the rate of between twelve and thirteen miles in a minute, but light passes through 195,000 miles in the sixtieth part of the same time.

186. As the eye is strictly an optical instrument, we must state that it is a law of optics that the rays of light, while passing through the same medium, proceed in straight lines, but that they are turned out of their course when they pass from a less into a more dense medium. They are then said to be refracted. This takes place when the rays of light pass from air into water, and it is by virtue of the same law that a common magnifying or double convex glass collects the sun's rays into a focus or point.

187. The eye has various appendages, which require some explanation. The first to be noticed are the eyelids. These are composed chiefly of a gristly substance placed under the skin that accurately fits the ball of the eye, and which is lined internally by a thin membrane called the conjunctiva, that turns over on the globe of the eye, and keeps it in its socket. Attached to the eyelids are the eyelashes, which protect the eye from too great a glare of light, from particles of dust, &c. Persons without eyelashes have always tender eyes. The chief purposes served by the eyelids are, 1st, to protect from external injury, and to exclude the light when they are closed; and, 2dly, to distribute equally over the eyeball the fluid which moistens it. This fluid is usually carried off as quickly as it is formed; but when the eye is irritated, or the mind affected by various emotions, it is then secreted in such quantity as to run over the eyelids in the form of tears. The source of this fluid is a gland, named the lachrymal gland, situated above the outer angle of the eye. Tears there secreted, pass downwards to the eye, whence they

293. What law of optics is cited?
294. What are appendages to the eye?

flow, through two small holes (puncta lachrymalia) near the inner angle of the eyelids, into a small receptacle called the lachrymal sac, placed immediately behind the inner angle, and from which there is a communication to the nostrils by what is called the nasal duct. This is the reason why, when tears are copious, a necessity for blowing the nose is felt. When the nasal duct is obstructed, as often happens, the nostril on that side is dry, and the tears run over the eyelids. The puncta lachrymalia may easily be seen by everting the eyelids, and looking at their inner angle; and the opening of the nasal duct may be seen by looking into the nostril of the horse. The two edges of the eyelids, when closed, form a channel, along which the tears flow. Birds have a third eyelid, at the inner angle of the two others, which they may often be seen moving. Fishes have neither eyelids nor lachrymal apparatus.

188. Others of the appendages are the muscles that move the eye, six in number. There are, besides these, two that move the eyelids. A broad circular one, which closes the eyelids, lies immediately under the skin. The other, which raises the upper eyelid, is a long muscle, and is attached to the bone deep behind the eyeball.

189. We now come to consider the globe of the eye, the parts composing which are seen in Fig. 38, representing a horizontal section of it. C, the cornea, is the transparent part of the eye in front, which, it will be seen, forms part of a lesser circle, and therefore projects more than the rest of the globe. It is set into the white part of the ball of the eye, and after steeping, can be taken out of it like a watch-glass. S, the sclerotic or hard coat, is the outermost one, or the white part of the eye seen in front. It extends over the whole ball posteriorly, and, from its toughness, forms its principal support. In the tortoise and in birds this part anteriorly has bony matter in its composition; and in the immense eye of the extinct

295. Use of the eyelids.
296. Source of the tears, and their course.
297. What of the muscles of the eye?
298. Define the cornea, sclerotic, and choroid coats of the globe.

reptile called the ichthyosuarus, it appears to have been composed of bony plates. The coat (X), which lies internal to the sclerotic, is called the choroid coat. It is lined on its inner surface, in the human eye, by a brownish-black paint (contained in hexagonal cells), which we see when we look deep into the eye. Its use seems to be to absorb the rays of light not required in vision. The colour of this paint is, as every one has seen, yellowish-green in the eye of the cat. It is chocolate-brown in the hare and rabbit, silvery-blue in the horse, and pale golden yellow in the lion and bear. In general, it is of a light shade in such animals as prowl by night. This paint is wanting altogether in albino animals, such as white rabbits or ferrets, and the red blood-vessels can then be seen in the eye. This coat seems to be continuous with a number or foldings called ciliary processes (K). The innermost of the coats of the eye (R) is called the retina, from its netted appearance. It consists of a very fine membrane, with the pulpy, half-transparent substance, which is continuous with the optic nerve (O),† expanded upon it. This is the seat of vision. All visual impressions must, in the first place, be made upon this expansion, and are then conveyed by the optic nerve to the mind.

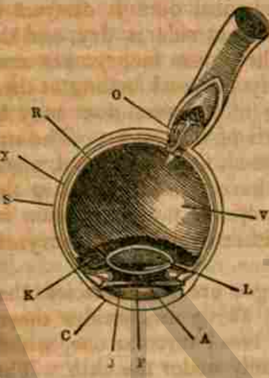

Fig. 38. Human Eye Dissected.*

190. The parts of the eye remaining to be described

* C, cornea. S, sclerotic coat. X, choroid coat. R, retina. O, optic nerve. V, vitreous humour. L, lens. A, aqueous humour. P, pupil. J, iris. K, ciliary processes.

† Also seen in Figs. 32 and 33. In Fig. 33 the two optic nerves are seen to join, and the fibres at this point are supposed partially to cross.

299. What gives colour to the eyes of animals?
300. Define the retina, and the optic nerve.

are the humours and the iris. A is the aqueous or watery humour, placed immediately behind (C) the cornea. It is divided into an anterior and a posterior chamber by (J) the iris, which floats like a curtain in it. The iris is the part that gives the blue, gray, or black colour to our eyes, and which has in its centre an opening (P) that enlarges or contracts according to the quantity of light to be admitted. It is supposed to possess a circular and a radiated set of fibres to effect this. Behind the aqueous humour lies the lens (L), the firmest of the three humours. Its form in the human eye, as seen in the figure, is something like a highly convex magnifying-glass. In fishes it is globular, and it is it that falls out like a pea when the eye is boiled.* Behind this, again, is placed the largest or vitreous humour (V), which appears of rather greater consistence than the white of an egg, and is enclosed in a very fine transparent membrane, ramifying also into its interior.

191. By the united action of all these parts, vision is produced. The cornea serves the purpose of a convex or magnifying-glass, to collect into foci or points the rays of light that pass from an object to the eye, and this effect is still further assisted by the lens placed behind it. The point where these foci are thus formed, is the retina; and the eye may be compared to the optical instrument called the camera obscura, which is indeed but an imitation of the eye itself. Those who have seen this instrument will know, that when the part corresponding to the cornea is presented to a landscape, there is an exact picture of it formed on the back part of the box. Kepler, the great astronomer, made the interesting discovery that the same thing may be seen in the eye. If the eye of a recently killed bullock be carefully stripped of its sclerotic and choroid

* A globular form of the lens (which refracts light in the highest degree) is rendered necessary from the greater refraction required, this being less when the rays of light pass from a dense medium like water to the eye, than when they pass from air to it.

301. Describe the humours of the eye, and the iris and pupils.
302. What of the lens?
303. Describe the organ of vision.

coats posteriorly, and the retina be supported by a piece of transparent silk, it may be placed in the hole of a window shutter looking out upon a landscape, and a diminutive but distinct picture of the whole may be seen depicted on the retina. From the thinness of the coverings of the eye in albino animals (such as the white rabbit), this exquisitely beautiful experiment may be performed even without removing any of the coats.*

192. It is truly wonderful to think that all the accurate perceptions of this sense are derived from the images of a crowded picture formed at the bottom of the eye, on a space so small that it may be covered with the point of the finger. What can be more astonishing than the fact, that the image of the sail of a windmill, six feet in length,

* The course of the rays of light coming from an object, and passing through the eye, is shown in Fig. 39, from which it will be seen that the object represented on the retina is inverted. The cause of this is, that the rays from different points (as may be observed in the figure) cross, and that those coming from the lower part of the object (*c*) have their focus on the upper part of the retina (*d*), while those from the upper part of the object (*a*) have their focus on the lower part of the retina (*b*). It must be understood that a double convex glass, or the eye, has the power of converging rays of light not merely to one focus or point, but to many foci. What is commonly called *the focus* of a glass or lens is merely its principal focus. Although, however, the objects are inverted on the retina, we see them in their proper position, that is, in a position corresponding with the sensations of touch. Various explanations of this fact have been attempted, but our space does not allow us to enter upon the subject.

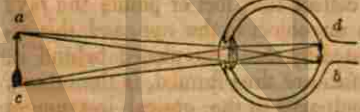

Fig. 39. Inversion of Rays on the Retina.

It may be mentioned here, also, that the reason why humours of different densities, and consequently different refracting powers, are used, appears to be, that the eye may be rendered what is called an acromatic instrument; that is, one that gives a clear picture of an object, without coloured fringes. These fringes used to annoy opticians and astronomers much, until the year 1729, when the happy thought struck a gentleman of the name of Hall to ask himself how nature obviated the difficulty in the eye. By using the same means, namely, constructing telescopes with lenses of different refracting powers, his success was complete.

304. Curious illustrations of this sense.

seen at the distance of twelve paces, occupies only the twentieth part of an inch on the retina, and that the image of the same sail, when removed to the limits of distinct vision, occupies, according to the calculations of M. de la Hire, only the eight thousandth part of an inch, or less than the sixtieth part of the breadth of a common hair! "We can never," to quote again Dr. Paley's words, "reflect without wonder upon the smallness yet correctness of the picture formed at the bottom of the eye. A landscape, of five or six square leagues, is brought into a space of half an inch diameter, yet the multitude of objects which it contains are all preserved—are all discriminated in their magnitudes, positions, figures, colours. The prospect from Hampstead Hill is compressed into a compass of a sixpence, yet circumstantially represented. A stage-coach, travelling at its ordinary speed for half an hour, passes in the eye over only one-twelfth of an inch; yet is this change of image distinctly perceived throughout its whole progress, for it is only by means of that perception that the motion of the coach itself is made sensible to the eye."

193. After what has already been said of the proofs of design furnished by other parts of the body, it is almost unnecessary, in that point of view, to direct attention to this admirable organ. Its mechanism is so clear that no one can mistake its objects. A celebrated philosopher held (and with good reason) that an examination of the eye was a cure for atheism; and he might have added, that it not only proves, beyond all doubt, the existence of a great first cause, but also, perhaps, more than any other organ, that our Creator's design is to mingle pleasure with our existence. If only what was necessary had been done, it has been well remarked, that nothing but the tame, dull outlines of objects might have been made sensible to us. But colour, endless in its shades, ever variegated in its tints, has been spread over the face of nature—for what purpose, it may be asked, if not to convey to us delight,

305. Name the moral reflections inspired.

and to prove that He who made us always wishes us to be happy.

194. Among even the lower tribes of the Radiata, indications of sensibility to light have been observed, but no distinct organs for this sense have been discovered. Ehrenberg has lately described some small spots in the rays of the star-fish, which he conceives answer the purpose of organs of vision. As we rise higher, visual organs are seen, but the Sepia is the lowest that has eyes constructed like those of the Vertebrata. The eyes of insects are called compound, being, in truth, immense aggregations of eyes, apparently to compensate for their want of mobility. The common house-fly has 8000 of these eyes; the dragon-fly 12,544; and some other species have upwards of 25,000.

195. The diseases of the eye are very numerous. The conjunctiva, lining the eyelids and reflected on the eyeball, the sclerotic coat (S, Fig. 38), and the iris (J), are particularly liable to inflammation. The ophthalmia that affected our soldiers in Egypt, generally commenced in the conjunctiva, and destroyed the eyes of great numbers. The lens (L) often becomes opaque, especially in old people, and causes blindness. When this happens, it is called cataract, and very frequently an operation is performed to restore vision. The duke of Sussex was successfully operated on a few years ago. The operation consists either in taking out the opaque lens, by cutting the cornea, or in pushing the lens downwards into the vitreous humour (V), out of the course of the rays of light. Blindness also arises from opacity of the cornea, closure of the pupil, disease of the retina or optic nerve, called amaurosis, &c.

To illustrate the sense of smell, a longitudinal section of the nose of a sheep can be easily made, keeping the saw as much as possible to one side, when the spongy or turbinated bones, which are covered with the Schneiderian membrane, and are convoluted to increase the extent of surface, may be observed. The structure of the nose of the cod or haddock is also curious. It does not communicate with the mouth, and ought to be shown. The olfactory nerves going to it

306. Singular varieties of structure in animals.
307. What of diseased eyes?

from the brain, may easily be exposed in the fish with a strong pair of scissors.

The organ of hearing lies deep in the bone, and is not easily got at. However, the membrane of the drum in a sheep can be very nicely shown, by taking off the bone containing the ear from the skull, and then cutting away the external bony canal leading to it, until it is exposed. The small bones of the ear may also be got at by breaking into the drum with a strong pair of cutting pliers. They should be taken out, and fastened with gum on a card covered with a piece of black velvet.

A simple apparatus to show the vibrations of the air, in imitation of the external ear, may be constructed by forming two pieces of firm Bristol board into a shape like a common funnel used for decanting liquors, cutting the narrower extremity slopingly, so as to leave an opening about two inches by one and a half, and gumming *loosely* over this a piece of goldbeater's skin. The other extremity may be made about seven inches in diameter. When this funnel is supported on a wire-stand, so as to bring the goldbeater's skin into a horizontal position, and some fine sand is placed on it, the vibrations produced by the air may be seen, by beating on a sheet of tin, or other strongly vibrating body, at the larger extremity. Any tinsmith will give the shape for the Bristol board.

The structure of the eye can be admirably shown. Direct attention to the puncta lachrymalia; to the appearance of the pupil, contracting and dilating as more or less light is directed on the eye; to the correspondence of the motions of the two eyes; the colour of the iris, &c. The muscles of the eyeball can be beautifully seen in the sheep, but they require a good deal of dissection. The globe of the eye may be easily shown, however. Get a bullock's or sheep's eye, clear off the fat, &c., and observe the optic nerve entering it posteriorly. Take hold of the optic nerve, introduce a pair of sharp scissors through its coats, rather more posteriorly than the middle of the globe, and cut the coats round transversely. The exterior sclerotic coat, the pulpy retina (often curled up) interiorly, and the choroid coat between these, will then be seen. Some of the vitreous humour will probably escape in making the section, and both it and the lens, lying behind the pupil, will be seen when the posterior section of the eye is removed. A number of lines on the choroid coat, radiating from the circumference of the lens, and called ciliary processes, may also be seen. The aqueous humour may be seen to escape when the eye is made tense (when entire), and the cornea is punctured. The iris may be examined when the humours are removed. A similar section of a cod's eye should be made to show the globular lens. The eye of a fowl may also be examined, and its bony sclerotic, third eyelid, &c. observed.

Such a section as has been mentioned should of course always be made, but the anatomy of the eye is made much more simple by having a horizontal section model of it. In this its coats, humours, &c., are all seen, and their relations may be comprehended with the utmost ease by young pupils. As these section-models are difficult to be had, and are expensive, some cheap ones have been constructed for teachers, which may be had, by applying to Messrs. Chambers, at five shillings and sixpence each.

To show the inverted image on the retina, the eye of a white rabbit answers well. It is seen best by candle-light, and when two or three lights are moved before the eye. All the muscles and fat must first of course be removed posteriorly.

A prism, to show the decomposition of light, and a small camera obscura, should be exhibited.

Fig. 39 is rendered more plain by colouring the upper rays red, and the under ones blue, or the reverse.

For figures to illustrate this section, see Lizars's Coloured Plates, pages 75, 76; Roget's Bridgewater Treatise, vol. ii. pages 384, 400, 401, 425, 464, 467.

SECTION X.

REPRODUCTION.

196. As the law throughout the whole of animated nature is, that each individual shall, after a period more or less limited, die, so also have arrangements been made to secure the reproduction of the various tribes of animals. The modes adopted by nature, in accomplishing this object, vary much, in some cases being very simple, in others more complicated. Among the simplest modes of propagation is that in which an animal divides into two similar halves, each half becoming a separate creature, which also, in due time, undergoes the same process. This takes place among monads and other animalcules. Another very simple mode of propagation is seen in the polype (Fig. 2), on the body of which a small bud appears, grows, and ultimately separates from the parent, to become an animal of the same kind. As we rise higher in the scale of creation, we observe that animals are either *oviparous*, that is, produced from an egg, or *viviparous*, that is, born alive. Three classes of the vertebrata—fishes, reptiles, and birds—as well as the great proportion of the inferior divisions of animals, are all *oviparous;* but the animals composing the highest of the vertebrate classes, the mammalia, are all viviparous. In both these divisions, however, we do not find that the animal produced has always

308. Simplest mode of reproduction.
309. Define oviparous and viviparous.

from the brain, may easily be exposed in the fish with a strong pair of scissors.

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To show the inverted image on the retina, the eye of a white rabbit answers well. It is seen best by candle-light, and when two or three lights are moved before the eye. All the muscles and fat must first of course be removed posteriorly.

A prism, to show the decomposition of light, and a small camera obscura, should be exhibited.

Fig. 39 is rendered more plain by colouring the upper rays red, and the under ones blue, or the reverse.

For figures to illustrate this section, see Lizars's Coloured Plates, pages 75, 76; Roget's Bridgewater Treatise, vol. ii. pages 384, 400, 401, 425, 464, 467.

SECTION X.

REPRODUCTION.

196. As the law throughout the whole of animated nature is, that each individual shall, after a period more or less limited, die, so also have arrangements been made to secure the reproduction of the various tribes of animals. The modes adopted by nature, in accomplishing this object, vary much, in some cases being very simple, in others more complicated. Among the simplest modes of propagation is that in which an animal divides into two similar halves, each half becoming a separate creature, which also, in due time, undergoes the same process. This takes place among monads and other animalcules. Another very simple mode of propagation is seen in the polype (Fig. 2), on the body of which a small bud appears, grows, and ultimately separates from the parent, to become an animal of the same kind. As we rise higher in the scale of creation, we observe that animals are either *oviparous*, that is, produced from an egg, or *viviparous*, that is, born alive. Three classes of the vertebrata—fishes, reptiles, and birds—as well as the great proportion of the inferior divisions of animals, are all *oviparous;* but the animals composing the highest of the vertebrate classes, the mammalia, are all viviparous. In both these divisions, however, we do not find that the animal produced has always

308. Simplest mode of reproduction.
309. Define oviparous and viviparous.

the form which it is ultimately destined to assume. Among *oviparous* animals we have already mentioned the frog as being, when hatched from the parent egg, essentially a fish before it becomes a reptile, and the fly and moth as being at first a maggot or a caterpillar; while, among *viviparous* animals, we find that the Marsupialia, including the opossum and kangaroo, are, when born, minute half-formed masses, totally unlike what they afterwards become. When born, the opossum, which, at its full growth, is an animal larger than a cat, is little larger than a pea; and the kangaroo, an animal at its full size as large as a sheep, is at birth hardly an inch in length. At this stage of its existence, the animal is transferred by its mother to a pouch which nature has formed in the skin of the belly of these singular creatures, and there becomes firmly fixed to a small nipple, to which it remains attached until its growth has greatly increased. The pouch continues to be the dwelling-place of the young animal until it can subsist independently of the parent, and many may have seen in our menageries the young ones gamboling about the mother, but escaping to the pouch upon the least alarm of danger. Something analogous to this arrangement is found among certain *oviparous* tribes, in which the eggs are hatched within the body of the animal. These are called *ovo-viviparous.* The shark is said to be *oviparous* in some circumstances, and *ovo-viviparous* in others.

210. Imperfect development at birth, and subsequent changes of form.

THE END.

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3. Davies' School Arithmetic.

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THE ACADEMIC COURSE.

1. Davies' University Arithmetic.

The scholar in commencing this work, is supposed to be familiar with the operations in the four ground rules, which are fully taught both in the *First Lessons* and in the *School Arithmetic.*

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The Treatise on Algebra by M. Bourdon, is a work of singular excellence and merit. In France it is one of the leading text-books. Shortly after its first publication it passed through several editions, and has formed the basis of every subsequent work on the subject of Algebra.

The original work is, however, a full and complete treatise on the subject of Algebra, the later editions containing about eight hundred pages octavo. The time given to the study of Algebra in this country, even in those seminaries where the course of mathematics is the fullest, is too short to accomplish so voluminous a work, and hence it has been found necessary either to modify it, or to abandon it altogether. The Algebra of M. Bourdon, however, has been regarded only as a standard or model, and it would perhaps not be just to regard him as responsible for the work in its present form.

2. Davies' Legendre's Geometry, etc.

Legendre's Geometry has taken the place of Euclid, to a great extent, both in Europe and in this country. In the original work the propositions are not enunciated in general terms, but with reference to, and by the aid of, the particular diagrams used for the demonstrations. It was supposed that this departure from the method of Euclid had been generally regretted, and among the many alterations made in the original work, to adapt it to the systems of instruction in this country, that of enunciating the propositions in general terms should be particularly named; and this change has met with universal acceptance.

3. Davies' Analytical Geometry.

This work embraces the investigation of the properties of geometrical figures by means of analysis. It commences with the elementary principles of the science, discusses the Equation of the Straight Line and Circle—the Properties of the Conic Sections—the Equation of the Plane—the Positions of Lines in Space, and the Properties of Surfaces.

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Descriptive Geometry is intimately connected with Architecture and Civil Engineering, and affords great facilities in all the operations of Construction.

As a mental discipline, the study of it holds the first place among the various branches of Mathematics.

5. Davies' Shades, Shadows, and Perspective.

This work embraces the various applications of Descriptive Geometry to Drawing and Linear Perspective.

6. Davies' Differential and Integral Calculus.

This treatise on the Differential and Integral Calculus, was intended to supply the higher seminaries of learning with a text-book on that branch of science. It is a work after the French methods of teaching, and in which the notation of the French school is adopted.

DAVIES' GRAMMAR OF ARITHMETIC:

OR,

AN ANALYLIS OF THE

LANGUAGE OF FIGURES AND SCIENCE OF NUMBERS.

This work gives the results of a very full and careful analysis, both of the Science and Art of Arithmetic, and offers some suggestions on the best methods of imparting Arithmetical instruction. Perhaps a more correct description of the work cannot be given, than to copy the following notice from the *New-York Tribune.*

"Grammar of Arithmetic, by Chas. Davies, L. L. D., (18mo. pp. 144.) In this work the language of figures and the construction of numbers are carefully analyzed. The alphabet, composed of the ten figures—the words derived from the alphabet, and the laws by which the figures are connected with each other, are all clearly explained.

"The analysis shows that there are but four hundred and eighty-eight elementary combinations in Arithmetic, each corresponding to a word of our common language; and that these combinations are so connected together as to be all expressed by only sixty-three different words. The system proposes to commit these words to memory, and then read the results instead of spelling them, as now practised.

"In another respect, the system proposes an important change—namely: to consider and treat all fractions as entire things, having a given relation to the unit one from which they were derived.

"We scarcely need say that the little work evinces the ingenuity and skilful mathematical analysis for which Prof. Davies' writings on this subject are justly celebrated. We commend it to the attention of practical teachers, believing that they will find it crowded with new and valuable suggestions."

Military Academy, Jan. 17, 1850.

"The Grammar of Arithmetic, by Prof. Davies, presents the subject in a new light. It so analyzes Arithmetic, as to impress the mind of the learner with the first principles of mathematical science, in their right order and connection; and the new rules for the reading of figures are of great practical value."

(Signed,) W. H. C. BARTLETT,
Prof. of Natural and Ex. Philosophy.
A. E. CHURCH,
Prof. of Mathematics.
D. H. MAHAN,
Prof. of Civil Engineering.

Extract of a Letter from Charles A. Coburn, *President of the Teachers' Institute of the State of New-York.*

"I do not know when I have before seen so small and unpretending a mathematical work, from which I have received so much valuable information and so many practical suggestions. If teachers would follow out your plan of spelling and reading with the Arithmetical Alphabet, it would save a world of talk. I think that most teachers would receive much benefit by a careful examination of the book, and would also be able to teach arithmetic more successfully and with less labor, by taking advantage of your suggestions."

"This work supplies the want which we felt as a scholar, and did our best to supply as a teacher of the 'Science of Numbers' though little to our own satisfaction."—*Windham County Democrat.*

"This is a curious, suggestive little book. Its author is a thinker beyond the ordinary surface, or the common pavements in the subject of Numbers. Long years of study and application have given him a long sight, and his book will interest teachers generally."—*Bangor Whig.*

DAVIES' LOGIC OF MATHEMATICS.

The Logic and Utility of Mathematics, with the best methods of Instruction, explained and illustrated. By CHARLES DAVIES, L. L. D.

"One of the most remarkable books of the month, is 'The Logic and Utility of Mathematics, by Charles Davies, L. L. D.,' published by Barnes & Co. It is not intended as a treatise on any special branch of mathematical science, and demands for its full appreciation a general acquaintance with the leading methods and routine of mathematical investigation. To those who have a natural fondness for this pursuit, and enjoy the leisure for a retrospect of their favorite studies, the present volume will possess a charm, not surpassed by the fascinations of a romance. It is an elaborate and lucid exposition of the principles which lie at the foundation of pure mathematics, with a highly ingenious application of their results to the development of the essential idea of Arithmetic, Geometry, Algebra, Analytic Geometry, and the Differential and Integral Calculus. The work is preceded by a general view of the subject of Logic, mainly drawn from the writings of Archbishop Whately and Mr. Mill, and closes with an essay on the utility of mathematics. Some occasional exaggerations, in presenting the claims of the science to which his life has been devoted, must here be pardoned to the professional enthusiasm of the author. In general, the work is written with singular circumspection; the views of the best thinkers on the subject have been thoroughly digested, and are presented in an original form; every thing bears the impress of the intellect of the writer; his style is for the most part chaste, simple, transparent, and in admirable harmony with the dignity of the subject, and his condensed generalizations are often profound and always suggestive."—*Harper's New Monthly Magazine.*

"This work is not merely a mathematical treatise to be used as a text book, but a complete and philosophical unfolding of the principles and truths of mathematical science.

"It is not only designed for professional teachers, professional men, and students of mathematics and philosophy, but for the general reader who desires mental improvement, and would learn to search out the import of language, and acquire a habit of noting of connexion between ideas and their signs; also, of the relation of ideas to each other.—*The Student.*

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