PRACTICAL
PHYSIOLOGY

DR. LANKESTER.

J. T. Morley

PRACTICAL PHYSIOLOGY;

BEING A

SCHOOL MANUAL OF HEALTH

FOR THE

USE OF CLASSES AND GENERAL READING.

BY

EDWIN LANKESTER, M.D., LL.D., F.R.S.,

ETC.

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PREFACE

TO THE

FIFTH EDITION.

My object in writing the 'School Manual of Health' was to supply an elementary treatise on those facts which must be known in order to secure the health of the body. I had hoped it would have served as a reading book in even primary schools; I find, however, that it has been principally used as a text-book in classes formed more particularly for the purpose of studying physiology in its practical relations to health and life. I have, therefore, ventured to change its name, and to add, what I at first thought might have interfered with its use as a reading book, a large number of illustrations. These will undoubtedly be of assistance to the scholar who may be expected to prepare for examination in class. They will also assist the teacher where access cannot be had to larger diagrams, such as those prepared by Mr. Marshall and Professors Goodsir and Turner. In order to render the work better fitted for classes, I have added a series of questions, to be used at the discretion of the teacher. I have also appended a glossary and a series of tables on various important subjects connected with the practical application of physiology to the maintenance of health and the preservation of life.

Melton House, Hampstead;
February, 1872.

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INTRODUCTION.

In introducing a new edition of my 'School Manual of Health' to the public under another name, I would make a few remarks on the subject of teaching physiology in schools.

Whilst all are agreed that the mental powers which man possesses, as distinguishing him from the brute creation, are susceptible of improvement and development by what we call education, there is not a little difference of opinion as to the method of conducting this education. For the male children of the more favoured classes of society it seems not to be doubted in certain classes that instruction in the dead languages and mathematics is the most desirable training they can undergo. For the sons of the less opulent, and the male members of the working classes, it is taken for granted that a knowledge of any language except their own is useless, and that writing, ciphering, geography, and history is all that ought to be required. With regard to the education of girls the general opinion is that the education of their minds does not demand dead languages, that mathematics are useless, and that a training in music and singing, with the acquirement of one modern language, is amply sufficient.

It is not my object here to enter into any controversy as to whether boys should be educated differently from girls, or as to whether the training of the mind of the son of a rich man should be different to that of the son of a poor man. I wish, however, to state my conviction as a physiologist that there is no anatomical distinction between the brains of men and women, or those of rich and poor people.

With regard to education, it appears to me that whatsoever is of advantage to the rich man is also of advantage to the poor man, and that, in so far as it can be afforded, the same training of the mind is of the same advantage to the poor as to the rich man. I would even go further, and say that which is good for the male is good for the female, inasmuch as there is no essential difference between the mental powers of men and women.

But leaving this great question, on which so much controversy exists, I am anxious to show that whatever difference of opinion there may be as to how far the human mind should be drawn out or educated in certain classes of society, that there are certain common facts or truths that should be communicated to all minds, whether rich or poor, male or female.

Every one recognises the importance of teaching to every human being the obligations of the moral law, and the child is taught both by its family and the nation that it may not steal, covet, lie, or commit murder. In the same Divine record in which the moral law was given to man for the guidance of his social life, we find a code of physiological laws given him for maintaining his body in its health and integrity. It may be satisfactorily shown that where man is negligent of his physical welfare, and invites by his ignorance the invasion of disease, that there he is morally impotent and incapable of obeying the spiritual laws of his nature.

It is not only amongst the Jews that we find that physiological laws were laid down for the guidance of the people, and even severe penalties attached to the voluntary breaking of these laws; but we find amongst the enlightened Greeks and Romans at various periods, the laws of life were recognised, and the importance of obeying them enforced by penalties.

In modern Europe the physical laws of existence seem to have been almost entirely ignored. The history of the great plagues which have from time to time visited the eastern and western hemispheres afford a melancholy indication of how entirely man has forgotten his dependence on physical laws for his health and existence.

In order to obey the laws of life it is not necessary that every individual should be profoundly acquainted with the structure of the human body and the intimate nature of its functions, but it is necessary that every one should so far understand these matters that he may avoid the most common causes of disease, and submit with alacrity to those laws which the government may impose upon him for the health and salvation of the community.

As an objection may be urged to the teaching of physiology on the ground of the subject being too complicated for laying before the minds of children, I would here indicate those "rudiments*" of the subject which I think might be taught in every school.

In the first place the human body is subject to the same laws as all other matter. It is composed of solid, fluid, and gaseous matters, which are identical with substances having the same qualities out of the human body. A knowledge of this fact should precede all others in teaching laws governing the existence of the human body.

In the second place, the pupil should be taught that these substances are composed chemically of the same elements as exist in other bodies, outside the human system. The most common elements in the human body are carbon, hydrogen, oxygen, and nitrogen. The chemical properties of these elements play a very important part in the life of the human body, and their principle properties must be understood to appreciate their influence on life.

In the third place, the human body is composed of various organs, each performing a special function. These organs have all a definite relation to each other. By their agency the chemical substances in the form of food enter into the body, and this food supplies the materials which, being distributed by the heart and blood-vessels to the various parts of the body, enable them to perform the actions which we call life. The great laws by which this life is maintained in its integrity, and disease kept at bay, are not difficult to understand, and it is by a knowledge of these laws

* A Committee appointed by the British Association to report on scientific education recommend that the "Rudiments of Physiology" be taught in schools.

that the nature of disease and death can be explained, and their occurrence prevented.

That disease and death can be prevented is a well-known fact; and certain diseases are called "preventible" by sanitary writers because their causes are well known and can be removed. It is not, however, possible by mere authority to prevent these diseases. The law can do much to remove those causes of disease which individuals are incapable of removing. It can compel a town to have a supply of water, but no law can compel people to use water. Unless individuals are instructed in the necessity of using water for the benefit of their health the law is useless. This is really the case with the whole of the sanitary laws of England. They are comparatively useless, because we have a population growing up around us, entirely ignorant of the nature of the laws which produce death and disease. It is thus that diseases spring up in homes long before those who are instructed in the means of their prevention can know anything about them.

There is abundant evidence to show that in certain towns and districts where disease and death have been unusually present, the adoption of sanitary measures has stayed the rate of mortality and diminished disease. Many towns in England have presented high rates of mortality, and on the adoption of sanitary measures the mortality has immediately decreased. Examples of this are so numerous that I need not repeat them here. Whenever the deaths of a district rise above a certain average, it is a well-known fact that it is due to the transgression of some obvious law of healthy existence.

In many town populations of England half the individuals die before they are five years of age. It cannot for a moment be supposed that this is the necessary destiny of humanity. The contrary, in fact, can be easily proved. There are many districts and families in England where infant death bears but a small proportion to the rest of the community. This clearly shows that in those districts where infant mortality is large, it must arise from one of two causes, either a wilful destruction of human life, or an ignorance of the laws by which it can be maintained. There can be little doubt that the latter is the cause. Where one child is sacrificed wilfully and maliciously, at least one thousand perish through ignorance.

The question, then, comes for consideration, as to how large an amount of useful *information* in the laws of life can be conveyed in the course of two or three years to boys and girls at school?

It may be difficult to point out what should be the minimum or maximum of knowledge to be communicated on this subject. The great difficulty is not, however, to estimate the amount of knowledge to be given, but to get teachers competent to the task. Provided however, the managers, masters, and mistresses of schools have determined that this subject of physiology should be introduced, it would not be difficult to find teachers. In every district of England there are young medical men who, with a proper text-book in their hands, have a sufficient knowledge of the science of physiology to communicate its rudiments to a class of intelligent children. There are also scattered throughout the country young men and, I am happy to know, young women, too, who have successfully passed examinations in Physiology in the Science examinations of the Committee of Privy Council on Education. But even should these aids be wanting, an intelligent teacher impressed with the importance of the subject, and bent on instructing his pupils, could easily employ any one of the numerous manuals of physiology as a reading-book in the school, and endeavour to explain to a class its meaning as far as he himself understands the subject. It is in this manner that physiology needs not to stand in the way of any other branch of tuition. The children must read; and it seems to me of much more importance that children should read about the wonderful structure of their own bodies than of distant lands, extinct empires, or even moral and didactic tales. An intelligent reader might easily take the opportunity whilst the pupil is engaged in reading about the structure of the eye, the hand, the heart, or the lungs of the body, to improve the subject and make it to exert a moral and religious influence on the child by pointing out the wisdom, the goodness, and the power of God, as exemplified in the facts of his own existence.

The teacher having been obtained, the question comes, how he should proceed? Should he at once commence with some interesting portion of his subject, as the brain, the heart, the eye, or the skin, and thus by a process of analysis place the nature of a human body before his pupils; or should he begin by showing the nature of the elementary parts of the human body, and, putting them together, at last show how they form a human body? I confess I am in favour of the last method. By teaching children that the human body is composed of certain elements which are found in water, air, and earth, they are prepared to understand the purely chemical nature of many of the vital functions.

Proceeding from teaching the principles of the chemistry of life, we may go on to give a knowledge of the special structures of the human body. The structure of the organs subservient to the function of digestion; the nature of the changes whereby the food we eat becomes converted into blood; the circulation of the blood, the changes it undergoes during respiration, and the structure of the heart and lungs, are not difficult things to teach intelligent children of from ten to twelve years of age. From these subjects they may advance to the study of the muscular system and the nature of animal mechanics. The nervous system, the seat of consciousness, intelligence, and emotion, may then be studied, and the physiological course closed with the structure and functions of the organs of the senses.

Having glanced at the subjects which I think should be brought before the minds of a class of pupils in a school, I would add a few words with regard to the method of teaching. Although physiology is usually taught by means of lectures, it is not necessary that it should be so. The teacher may use some of the elementary books in physiology, such as the present volume, which was drawn up at the request of the Irish Board of Education, and, getting a class to read a few sections, might explain each section if necessary, and before reading the sections at the next lesson make an examination on the last, taking care that each pupil understands what he or she has been reading.* These lessons should be illustrated by experiment when the chemical part is brought before the class, and the elements spoken of should be demonstrated. A very few simple experiments will impress on the mind of the pupil the nature of the four organic elements, and their principal chemical compounds are always at hand to exhibit and demonstrate their properties.

In the same way, when the tissues of the body are referred to, it is not necessary to have recourse to, or even allude to, the dissection of the human body. The butcher's shop will supply ample illustrations of the tissues of which the human body is composed. A mutton chop in the hands of a competent teacher would give illustrations of nearly every tissue in the human body. In the same way particular organs, as the tongue, the ear, the eye, and the teeth, may be advantageously demonstrated in the head of a sheep; whilst a mouse, rat, pig, or rabbit, in the hands of a skilful teacher, would afford ample instruction in the position of the lungs, heart, and abdominal viscera. Besides such direct appeals to the senses as could be afforded by demonstrations of this kind, there are few subjects for which provision has been more amply made in the form of diagrams. Some of our great physiologists have directed their attention to this subject, and the late Professor Goodsir, with Professor Turner, have published a series of diagrams expressly intended for the assistance of teaching classes in schools. A number of admirable diagrams, life-size, have also been published by the Committee of Council

* A glossary and questions have been added to the present edition for this purpose.

on Education, and executed under the direction of Professor Marshall, of University College, London. Either of these sets of diagrams would be found of great assistance in teaching a class of children the "rudiments of physiology." When I consider the immense facilities for teaching the great facts of physiology as compared with any other branch of natural science, I confess I am astonished at the objections urged by some teachers to the introduction of the study of physiology into our schools as too difficult.

An important practical question arises here, and that is, How much time ought to be given to these studies? It is the error of masters and mistresses in schools that they think natural science may be taught in leisure moments, and that a few lectures in the course of a year will suffice to give their pupils all the information that is necessary on these subjects. If they would reflect on the fact of how large a portion of time is given to the study of subjects of which, when the education of their pupils is completed, they exhibit but a comparatively small amount of accurate knowledge, they will see that to give children a sufficient amount of knowledge of any branch of natural science, to make it available in life, they must devote to it as large an amount of time and labour as to any other subject of equal importance. No boy could be expected to know anything of Latin by a few lectures delivered in the course of his annual studies. Physiology, if it is to be taught at all, must have regular and systematic attention. I would suggest that two hours a week, at least, should be secured for this branch of teaching. If extra time can be given for preparation for the lessons received in these two hours so much the better. What I would wish to impress is this, that little or no good will be effected if the subject is made a matter of indifference with the teacher or the pupil. The only way in which benefit can be derived is by making the pupil thoroughly understand the subject, and feel the importance of the facts it imparts.

The advantages which this knowledge, early imparted, would confer, are very abundant. One of the great drawbacks to all our sanitary legislation is the want of knowledge on the part of those for whom so many Acts of Parliament are enacted. It is useless to give powers to corporations and vestries, if the individuals of whom they are composed are ignorant of the use or value of the powers which are conferred upon them. If people do not understand something of the nature of the laws by which contagious diseases are multiplied and diffused, it is hopeless to expect that these diseases will cease to depopulate and destroy. I might add here a larger number of illustrations, but they will occur to every intelligent mind.

There is scarcely any class in the community to whom, independent of its purely personal application, a knowledge of physiology would not be of benefit. Beginning at the top of the social scale, I would refer to statesmen—to those to whom we must look for passing sanitary laws. Unless there is on their part a knowledge of the laws of life, their sanitary enactments will fail to accomplish the objects for which they have been brought into existence. Much of the unsatisfactory, indecisive, and patchwork character of our present sanitary legislation is due to the want of a knowledge of the ordinary laws of life on the part of our legislators. A universal education in physiology would undoubtedly catch all our statesmen, but if our universities would only insist on a pass-examination in physiology for all candidates, it would do much towards the introduction of this subject into our higher, middle-class, and even lower schools.

Next to our statesmen come our professional men; and first I would speak of the clergy of all denominations. In visiting the sick and poor, and in preaching to all, they have great opportunity of inculcating the necessity of obedience to those laws by which God governs the natural life of man. The clergyman can with propriety point out that obedience to those laws is life and health, and that disobedience is disease and death. Should he be a missionary to the heathen, with how much more influence will he be able to preach the truths of Christianity when accompanied by the knowledge of the nature of health and life possessed by those who have studied the science of physiology in civilised communities.

I pass from the clergyman to the lawyer. Although many of our great lawyers have exhibited more than an ordinary amount of physiological knowledge in cases that have come before them, it is not considered necessary that the great bulk of the legal profession should possess any knowledge of physiology whatever. Yet how large a number of cases that come before our courts of law involve points which only a knowledge of physiological laws can settle.

This is more especially the case with the Coroner's Court, where the investigation turns almost wholly upon questions connected with the structure and functions of the human body.

Passing from these purely professional classes, I come to the professions of the engineer and architect. Wherever the problem is to supply air to human beings, whether in railways, mines, ships, or houses, there a knowledge of the laws by which life is maintained is essential to those who design and build up these works. How often do we find the greatest works of the engineer and architect marred by the fact that he has ignored the simplest conditions of human existence.

From this class of professional workers we may pass on to those engaged in literature. However distinguished our great authors may be, instances are not wanting in which they betray a very palpable amount of ignorance of the laws of life. To those whose professional avocations lead them to speak on physiological subjects, it is often a source of great annoyance to find that their remarks have been thoroughly misunderstood by the ignorance of physiology of those whose duty it is to supply information through the press.

Passing from the professional to the middle classes, there are several public functions which they have to perform which render it imperative that they should be acquainted with the principal facts which relate to the preservation of life. It is from this class that the council-men of our corporation, the members of our vestries, and boards of guardians are principally drawn. To these bodies the government gives permissive powers to carry out the various Acts of Parliament which have been passed for sanitary purposes. Where the members of these bodies are ignorant of the laws of life, then disease and death stalk through the population committed to their charge, and the living inhabitants have to pay the penalty in hard cash for the ignorance displayed by their representatives. Those bodies are not aware, through the ignorance of physiology of their members, that disease and death are the most expensive luxuries in which they can indulge.

From tradesmen I pass to working men. Our working classes, whether employed in the open air or in close rooms, need to know the causes of death and disease. By ignorance on their parts of the nature of fresh air, they frequently surround themselves with poisonous atmosphere full of the germs of disease and death. The workshop and the factory are frequently the source of a predisposition to disease, not suspected by those who work in them.

The wife of the working man is equally ignorant of the way to keep her home sweet and pure, and of the causes that lead to the death of her husband and children. Neither the working man nor his wife are ever instructed in the nature of the daily food they take, so as to economise the small wages they receive, or to avoid spending their money on that which is utterly incapable of sustaining their health and strength. The utterly absurd views they entertain of the nature of alcoholic beverages ought to be corrected by a knowledge of the poisonous nature of the drinks which a large number of them take in quantities, at once reducing their power of work, and leading to premature poverty and death.

If in these remarks I have failed to convince my readers that boys ought to be taught in all our schools at least the rudiments of physiological knowledge, I would ask that this information be given to girls. To them, as assistants of their mothers in poor men's families, and as nursemaids in the families of the rich, a knowledge of the laws of life is essential. If they are ignorant of the structure and functions of a child's body, they make mistakes which are constantly leading to the destruction of infant life. It is the girl that becomes the mother, whether in the lower or higher classes of society, and I have no hesitation in expressing my conviction that the large mortality of children under five years of age is not due to vice or crime, but to ignorance. At least two thousand children are suffocated annually in bed with their parents or nurses in England and Wales, and not five per cent. of these cases can be traced to vice or crime. The cause of this premature death is the ignorance of the mother or nurse of the necessity of procuring for these children a due supply of fresh air. The cruelty of neglecting this branch of education is felt by the poor women themselves, when they reflect that they have lost their children through ignorance of the simplest laws which regulate the life of human beings.

In every relation of life it is most important that the woman should understand the causes of disease in her family. She is essentially the mistress of the household, and if she neglects the care of her children, or the superintendence of her servants, unnecessary disease and premature death will be the result. One of the great causes of the prevalence of preventible diseases and deaths all over the land is the utter and entire ignorance of the majority of females of the laws which govern healthy life. Even with regard to that most destructive of diseases—consumption, my friend, Dr. William Budd, says of all diseases it might be most easily prevented. But in order to do this our women, our mothers, our mistresses of households, must be instructed in the nature of the laws which govern the development and progress of this disease. The sum of human suffering that might be prevented, and the amount of wealth that might be saved, by a knowledge of the laws of disease is incalculable. And yet I find in the prospectus of a new "College for Women," that the subject of physiology is not contemplated as a branch of study in that institution. As long as this subject is thus slighted and neglected in all our plans and systems of education, so long will the miseries that arise from premature disease and death occur, and so long will poverty and physical debility obstruct the progress of mankind in the path to wealth and happiness. On this, above all other subjects, it may be said, in the language of our great poet, that

> "Ignorance is the curse of God;
> "Knowledge is the wing wherewith we fly to Heaven."

A SCHOOL MANUAL OF HEALTH.

CHAPTER I.

ON THE CONSTITUTION OF THE HUMAN BODY.

1. We are told in the Bible that "God created man of the dust of the ground, and breathed into his nostrils the breath of life," and we now know that man's body is composed of the same elements that we find in the earth beneath our feet. If we take a portion of the flesh of man, and examine it chemically, we find it to consist principally of four elements which are found commonly in the things which surround us in this world. These four elements are called the organic elements, because they are universally found present in plants and animals which are also called organic beings, on account of the organs they possess, by means of which they carry on their life. The names given to these four elements are Carbon, Hydrogen, Oxygen, and Nitrogen.

2. Of these four, carbon is the only one that is solid at the ordinary temperatures of our atmosphere. In its impure forms we know this substance by the names of charcoal and coal, but in one of its purest forms it constitutes the diamond, which is the most

precious of all gems. If a portion of a plant or an animal is exposed to a slow heat, the other elements are driven off, and the carbon in the form of charcoal is left. Carbon is easily burned in the air, and by its means heat is obtained from coals, candles, gas, and other substances in which it is contained. It is very important to recollect this property of carbon, as we shall find that it plays an important part in heating and carrying on the functions of the human body. Carbon, when it combines with oxygen gas, forms a gas called carbonic acid, which is constantly being thrown off from the lungs of animals. It is a very poisonous gas, and when retained in the blood destroys life, and when allowed to accumulate in the atmosphere is injurious to life. A human body weighing eleven stones, or 154 pounds, contains twenty-one pounds of carbon.

3. Hydrogen, the next element, is a gas. It is the lightest body known in nature. It unites with carbon, and forms the gas which is burned to light our streets and houses. Like carbon, hydrogen is very inflammable, and burns in the air with a flame. The flames of a coal fire and the burning jets of gas are due to hydrogen. When hydrogen burns in the air, it unites with the oxygen in the air, and the vapour of water is formed. All water is composed of the two gases, hydrogen and oxygen. Hydrogen and carbon are contained in human food, and, coming in contact with the oxygen of the air held in the blood, they are consumed, and are the great agents by which the heat of the body is maintained. In a human body weighing 154 pounds there are fourteen pounds of hydrogen.

4. The third organic element is oxygen. It is a gas, and one of the most active elements in nature. It unites with other elements, and causes them to burn. It unites with carbon and forms carbonic acid, and with hydrogen and forms water. It is one of the gases that enters into the composition of the atmosphere, and exists in the proportion of twenty-one parts in every hundred. It enters largely into all compounds in the human system; and a body weighing 154 pounds contains 111 pounds of oxygen. A more active form of it called *ozone* is found in pure atmospheric air.

5. Nitrogen, the fourth of these universal elements, is by itself far less active as a chemical agent than the other three. It is found in less quantities in the human system; and a body weighing 154 pounds contains but about three pounds and a half of nitrogen gas. It is, nevertheless, a very important element, as it enters into the composition of those organs, as the muscles and nerves, which are most important to life. When combined with other matters it may give rise to very violent chemical action—as in detonating powder. Nitrogen is an abundant element in nature, as it makes up with oxygen the bulk of the air of the atmosphere. A hundred parts of atmospheric air contain seventy-nine parts of nitrogen.

6. Besides these organic elements, a human body weighing 154 pounds contains four pounds of other elements. These consist principally of the metals calcium, sodium, potassium, and iron; and the non-metallic elements, sulphur, phosphorus and chlorine. These elements, though forming so small a proportion of the composition of the whole body, are, nevertheless,

essential to life. For example, the bones are composed in equal parts of an animal and earthy matter, the latter consisting chiefly of the two elements, phosphorus and calcium. In the human body of the weight above stated, there are one pound twelve ounces of phosphorus, and two pounds of calcium. Calcium is the metal of which the earth lime is an oxide.

7. The elements above mentioned are not found pure in the human body, but are united together, forming a number of compounds, out of which the various organs are formed. The compounds thus produced are very numerous, but the principal are water, gelatine, albumen, and fat. A body weighing 154 pounds contains 111 pounds of water, fifteen pounds of gelatine, four pounds and a quarter of albumen, about the same quantity of fibrine, and twelve pounds of fat.

8. Water is a most important constituent of both plants and animals. It seems as if all organic beings were so much organized water. In the vegetable kingdom sea-weeds and water-plants are often found to consist of much more than half their bulk of water. Naturalists tell us of jelly fishes that contained not more than ten grains of solid matter to one pint of water. All the food of the higher animals is dissolved in water before it is appropriated to the use of their bodies, whilst many of the lower animals pass their entire existence in water. Just as the human body is composed of large quantities of water, so is it necessary that the food of man should contain a large proportion of water.

9. All animal bodies are composed in great measure

of minute ultimate parts, which are called *cells*, and of a substance in which these cells lie. These cells are little vesicles or bladders, two or three thousand of which do not measure more than an inch; the walls of these little sacs, and the substance between them, are composed of a jelly-like body, which is either an albumen or a gelatine—in bone and membranes we find *gelatine* properly so called. This substance is made up of all four of the organic elements, and is insoluble in cold, but soluble in hot water. When any portion of an animal is boiled in water, the gelatines are dissolved. When the water containing gelatine is allowed to cool, it becomes more or less solid, and forms what is called a *jelly*. Gelatine is more abundant in the skin and bones than any other part of the animal body. A coarser form of *gelatine* is obtained from the skin of animals, and is called *glue*. Gelatine forms an insoluble substance with tannin, which is found in oak bark; and the skins of animals submitted to the action of a solution of tannin are converted into what is called *leather*.

10. *Albumens*, like gelatine, contain all the organic elements, and constitute the principal part of the muscles and nerves of animal bodies. Albumens differ from gelatines in becoming more readily decomposed after death. They are more closely connected with life. One sort of albumen is found in the muscles, and another in the nerves. Albumens are also found in the products of plants. Gluten is found in wheat-flour, in barley, oats, and maize. Other kinds of albumen are found in smaller quantities in the same things, and are present in the blood of animals.

Albumen constitutes that part of the egg which is known as the "white."

11. *Fat* is a most important constituent of all animals. Everywhere in the body of animals fatty matter is found under the skin and between the muscles. Fat differs from the three last compounds in containing no nitrogen, and but little oxygen. Although not directly aiding the functions of life, it contributes to many of its secondary functions, and is essential to the proper structure of all animal bodies. Fat, consisting almost entirely of carbon and hydrogen, is a substance readily burned. From the fat of animals candles are made; and it appears that in cold weather animals burn, as it were, the fat of their own bodies. Most animals get fat in the summer, and become thin in the winter from consuming their own fat in the process of making their bodies warm. This is remarkably the case with animals which hybernate, which enter upon their winter-sleep quite sleek and fat, but wake up in the spring meagre and thin.

12. Besides these compounds there are a great many others found in animal and human bodies. The food which they take whilst subserving the purposes of life, is transformed into compounds which appear in the blood, the liver, the spleen, the kidneys, and the various glands of the human body. They indicate that, during the performance of the functions of life, a vast number of chemical changes go on in the body, which are essential to its health and well-being.

CHAPTER II.

ON THE NATURE OF THE FOOD SUPPLIED TO THE HUMAN BODY.

13. All the substances that are found in the bodies of animals, and also of plants, are supplied from without. The cells of which plants and animals are composed absorb the matters of which they consist from the world around them, and these matters are called their food. Plants differ from animals in absorbing their food by their surface, whilst most animals have an internal bag or *stomach*, from the inside of which the food is taken up; and there is an orifice leading to this bag called a *mouth*. The food of the plant is also different from that of the animal. The plant takes up mineral substances, the chief of which are carbonic acid and ammonia, whilst animals take up substances which are formed in the tissues of plants. The life of the plant depends on its changing mineral substances into organic compounds, whilst the life of the animal consists in changing organic compounds into mineral matters. The life of the plant ends where that of the animal begins, and the life of the plant begins where that of the animal ends. Animals, in dying, give out the carbonic acid and ammonia, on which plants feed. Carbonic acid and ammonia contain the four organic elements—car-

bon and oxygen in the first, and nitrogen and hydrogen in the last.

14. Animals obtain the principal part of their food from plants; and when they feed on animals, as man feeds on sheep and oxen, the animals they eat have obtained their flesh from the vegetable kingdom. If regard is had to what man takes, it will be found that all his food may be included in three great classes. First, food in which all four organic elements are present; second, food in which all these elements are present, except nitrogen; and thirdly, substances or food which do not contain the organic elements, such as salt and the other mineral matters. They may be called nitrogenous, non-nitrogenous, and mineral foods. These substances are not, however, supplied separately, but are all contained in varying proportions in the food we eat. Thus, bread contains the nitrogenous principle fibrine, and the non-nitrogenous principle starch, whilst all kinds of meat contain fibrine, and the non-nitrogenous principle fat. In addition to the three groups of substances now mentioned, there must be water in all kinds of food. As we have seen (§ 8) three fourths of the human body consists of water, and as the food supplied to the body must be like the substances of which the body is formed, a large quantity of water must be taken in food.

15. The necessity for the supply of food to the body arises out of the fact that the life of man depends on the continued use and destruction of the particles of which the body is composed. If a man sits at one end of a pair of scales, and puts weights at the other, he will find that the longer he sits the lighter he grows. Whilst he moves, breathes, thinks,

or feels, certain portions of his body are being converted into gas and liquids, which principally pass from his lungs and kidneys. Now this loss must be supplied. The loss is sustained by every part of the body, and food is taken to supply the loss.

16. The loss sustained by the body during life is due to two causes. First, the action of the muscles and nerves in sustaining life consume certain particles of the body, which having been used are cast off from it by the lungs and kidneys. It is by this burning or consuming that the human body, like that of other animal bodies, has a temperature above that of the surrounding atmosphere, which is called *animal heat.* Thus the body of a human being in health is always kept at a temperature of ninety-eight degrees of a Fahrenheit's thermometer. Other animals maintain other temperatures, and their heat is mainly due to the burning in the blood of the food they eat in contact with the atmosphere which they breathe. According as the substances of the food are used for these two purposes they are called flesh-forming and heat- or force-giving. Though the flesh-formers can also supply force, and are necessary from time to time to assist the force- or heat-givers—yet the heat-givers cannot alone form flesh or help in forming it, since they have no nitrogen.

17. The flesh-forming principles of the food are known by the names albumen, gluten, and casein, and are contained in vegetable as well as animal foods. A sort of albumen, called *gluten*, is contained in the flour of wheat, in barley, oats, maize, potatoes, and other kinds of vegetable food. Another sort of albumen, called sometimes *fibrine*, constitutes the prin-

cipal part of the flesh of animals, and is obtained from dead blood. Other varieties of albumen are also found in small quantities in various kinds of vegetable food, but more especially in the white of eggs, in the blood of animals, and in the nervous system of animals. All albumens coagulate by exposure to heat, and this property is familiarly known by the hardening during boiling of the "white" of the egg. *Casein* is found in peas, beans, and lentils in the vegetable kingdom, where it exists in larger quantities than either gluten or the other albumens in other vegetable foods. It is also found in milk, and cheese when separated from milk consists principally of casein.

18. All these substances contain carbon, which may be separated, and is capable of giving out heat and other forces by uniting in the system with oxygen, but the non-nitrogenous substances contain larger quantities of carbon, and are especially employed in the generation of heat and other forms of force in the body. The force-giving substances are starch, sugar, and fat. *Starch* is especially a vegetable product, and is found almost universally present in vegetable substances. Wheaten flour contains sixty parts in the hundred of starch; barley and oats contain it in the same proportion, whilst rice contains at least eighty parts in the one hundred. Potatoes consist largely of water, but possess twenty-five parts in the hundred of starch. Starch contains no nitrogen, and consists in every twenty-one parts by volume of six of carbon, and five of oxygen, and ten of hydrogen. The two last elements exist in the same quantities in which they form water, and when starch is taken as food

the carbon alone is chemically changed. Starch, although insoluble in water, is easily diffused through it, and when heated with water mixes with it and forms a thickened compound. Hence, when flour is boiled in water it thickens, and thus puddings and dumplings are made. Arrowroot, tapioca, sago, and corn-flour, which is made from maize, consist principally of starch, and form thickened compounds when heated with water. Starch is not taken up into the blood in its natural form, but is converted into sugar in the mouth by the action of the saliva. Hence the importance of allowing all foods containing starch to remain in the mouth for a little time before they are swallowed.

19. *Sugar* has the same general composition as starch. It is, however, soluble in water, and when taken into the stomach is readily absorbed and taken into the blood. It has two forms, which are called cane-sugar and fruit-sugar. They both act alike on the system. Fruit-sugar is found in fruits, and is especially contained in the fruits of plants, as grapes, figs, plums, pears, and other sweet fruits. Cane-sugar is crystallisable, and is separated from the sugar cane, beet, maple, and other plants, for dietetical use; all the sugar ordinarily employed for food and the manufacture of sweetmeats is of this kind. Sugar is contained in small quantities in all kinds of vegetable food. Fruit-sugar undergoes the process known by the name of *fermentation*, by which the sugar loses a certain quantity of carbonic acid, and is converted into the compound known by the name of *alcohol*.

20. The other force- or heat-giving substance is *fat*. In this term is included all those substances which are

called by the names of oil, suet, tallow, grease, butter, and lard. They all contain compounds having the same general nature, and consisting principally of carbon and hydrogen, with a small quantity of oxygen. Although not soluble in water fat is rendered soluble in the stomach during the process of digestion, and is thus taken into the system. It acts in two ways on the system. First, like starch and sugar, it assists in maintaining animal heat, moving and nerve-power, and in the performance of this function it acts more efficiently than either starch or sugar, as not only is the carbon burned in the system but also the hydrogen. As far as this function goes, one pound of butter or lard will give out as much heat as two pounds and a half of starch or sugar. A second function of fat is that it is deposited in the body, and forms what is called adipose tissue or fat. A certain quantity of fat (11) is essential to the constitution of the body, and without it the system is not properly nourished. So essential is fat to the body that in certain diseases—as consumption—where it is not found in proper quantities, cod-liver oil and other fatty compounds are given for the purpose of making people fatter. Fat is obtained as food from both the vegetable and animal kingdoms. Salad oil is a familiar instance of the former, whilst all animal food contains it in larger or smaller quantities. Pork contains more fat than mutton, and mutton than beef.

21. All food contains saline substances. If we burn a portion of the flesh of any animal we may drive off the carbon, oxygen, hydrogen, and nitrogen, and "ashes" are left. These ashes are the saline and mineral constituents of the animal. They exist in

the blood and tissues, and are as essential to the life of the animal as the other products. Like the elements contained in the other compounds, they are constantly being carried off from the body, and need to be renewed in the food. Whilst food is being cooked, especially in boiling, these saline matters may be lost. Care should be taken to supply them in the form of uncooked food. Water, milk, fresh vegetables, as salads and uncooked fruits, are all means of supplying these compounds to the system. One of the most important of these compounds is *phosphate of lime.* This substance enters into the composition of the bones, of which it forms forty per cent. When it is deficient, the bones are soft and unable to resist the action of the muscles attached to them, and persons thus afflicted become more or less deformed. The deficiency of this substance is a characteristic feature of some diseases, and its administration medicinally has been found very beneficial. It is contained in wheat, barley, oats, and rye, and from these sources the chief supply of it to the human body is derived. These plants require phosphate of lime for their growth and the perfecting of their grains: hence it is supplied artificially by the farmer. The knowledge of the method of procuring and preparing this substance for manure is one of the triumphs of modern chemistry, and has been the means of increasing and cheapening the supplies of corn for the sustenance of man. A diet deficient in substances yielding the phosphate of lime is injurious to man, and should be avoided. It is on this as well as on other accounts that a diet comprising bread made from wheat flour forms the food of the strongest and most vigorous races of mankind. Another mineral substance found in the body is chloride of sodium —*common salt.* The quantity contained in a body weighing 154 pounds is three ounces and three quarters. So important is this substance to health that serious diseases have been known to be produced by its being withheld. It is the only substance besides water which is taken in a mineral form as food. It is used alike by the rich and poor. The animal world needs it as well as man, and interesting records have been given by naturalists of the pilgrimage made by animals to the sea-shore or to salt lakes for the purpose of procuring this necessary of their existence. Amongst the ashes is found *potassium.* Although it exists in less quantities than the metals of lime or soda, it nevertheless seems to act a very important part in the system. Whilst common salt is found in the blood, the salts of potassium are found in the flesh. One of the consequences of a diet consisting of salt meat is scurvy. In meat preserved by salting, the chloride of sodium is made to take the place of the salts of potash, and in this way a proper supply of potash is not afforded to the system. Our sailors in the navy formerly suffered very greatly from scurvy, but since the introduction of lime-juice, or preserved vegetables, as a part of their diet, the disease is now seldom seen. The most efficient cure for scurvy is fresh vegetables of any kind, and as it is known that they contain considerable quantities of the salts of potash, it is inferred that they cure this disease by supplying this necessary substance to the blood. Whether the salts of potash supplied in any other form would be as beneficial has not been tried, but there can be little doubt that the habitual use of uncooked fruit or vegetables in the form of salad is a valuable means of maintaining health. There is yet another mineral substance found in the human body the presence of which, though in small quantities, is most essential to health, and that is *iron*. That this metal exists in the human body is attested by the somewhat melancholy experiment practised by those who advocate the ancient practice of burning, and who, instead of preserving the ashes of their friends in appropriate urns, have extracted from them the few grains of iron they contain, and worn it in the form of a memorial ring. The absence of iron from the body is indicated by certain well-known symptoms, as paleness of the face and lips, palpitation of the heart, and general weakness; and this state of the system is only to be remedied by the administration of doses of iron in a medicinal form.*

22. Besides the foregoing substance, the system seems to require the addition to food, in small quantities, of those materials which are known by the name of *condiments* and *spices*. They act upon the nervous system, and seem to stimulate the stomach to produce those changes in food which are necessary to its digestion and preparation to convert it into blood. In this way salt seems to act as a condiment. Mustard and pepper, onions, sage, and thyme, are all used in the same way. Nutmegs, cinnamon, and cloves, which are eaten with sugar, act in the same manner, and are known as spices. There is no doubt, also, that small quantities of alcohol taken with food

* See 'Good Food.' By Dr. Lankester. Routledge and Sons. Price 6*d*.

act similarly, and is the foundation of the pernicious practice of taking alcohol for the sake of its intoxicating effect.

23. *Alcohol*, which is the product of the fermentation of sugar (19), acts as a powerful stimulant on the nervous system. It is the basis of wines, beers, and distilled spirits, and is one of the most dangerous articles of food. When taken in large quantities, in any of the above forms, it acts most injuriously on the stomach, liver, brain, heart, and other organs of the body. So destructive is the effect of this agent on the whole body that large numbers of persons avoid its use altogether, and thus have successfully demonstrated that the use of this agent is not necessary to health. If, however, it is employed, it should not be taken without other kinds of food, as, even diluted in the form of beer or wine, it is found to act injuriously on the delicate membranes of the stomach and other digestive organs. When taken in quantities beyond that required to act as a healthy stimulus to the nervous system, it is found to destroy the quality of the blood, to congest the membranes of the brain, to produce incurable affections of the liver and kidneys, and to effect changes in the muscular structure of the heart, the result of all of which are painful and lingering diseases, or sudden death.

24. There is another group of substances taken as food, of which we must take notice, and these are tea, coffee, and chocolate. Although the leaves of tea and the seeds of coffee and chocolate have a very different composition, they all agree in containing an active principle which acts powerfully on the nervous system. This principle is called *theine* in tea, *caffeine*

in coffee, and *theobromine* in chocolate. It is absolutely identical in tea and coffee, and only differs slightly in chocolate. Tea contains, besides theine, volatile oils, which give to it its peculiar flavour, and also tannin, an astringent substance. Strong tea acts injuriously on the nerves, and, when taken of the usual strength, it is apt to interfere with the digestion of meat, on account of the tannin coagulating the albumen. Tea is best taken with milk and sugar, as is the usual practice of England; but it should be recollected that, whilst small quantities of this beverage, like alcoholic beverages, may be taken with impunity, that large quantities interfere with healthy digestion, and lay the foundation of serious disease. Coffee contains less theine than tea, but as larger quantities of the roasted seeds are used than of tea to form a beverage, the nervous system is acted on as much by the use of one as the other; and coffee, like tea, may be taken to excess. Coffee also contains volatile oils, and an acid, which gives it its flavour; but it contains no tannin. Chocolate, or cocoa, differs from tea and coffee in containing large quantities of fat. Cocoa-paste contains half its weight of fat, and also a certain quantity of albumen. It is on this account that cocoa may be regarded as a substantive article of diet. It contains less of the active principle than either coffee or tea. Cocoa and chocolate are the same thing, but the latter term is used when the seeds of the cocoa are ground into a paste, and vanilla is added to flavour the compound.

25. The foregoing substances enter more or less largely into the daily food of man. Great as is the variety of food which he takes, each form of food is

capable of being analysed, and the quantity of flesh-formers, force-giving, and mineral matters that it contains ascertained. The quantity of those substances required by man must vary according to age, sex, climate, size, health, and daily work. The young of the mammalia are all fed for some months after their birth by *milk*. This liquid contains all the substances necessary to a healthy diet. In one hundred pounds of milk there are five pounds of casein, three pounds and a half of butter, four pounds and a half of sugar, and one pound of mineral matters; the rest is water. The milk of all animals may be used as food by man; and although it is the especial food of infants, it is an excellent addition to the food of man at all ages. Butter is separated from milk, and used as a separate article of diet, whilst the casein and water are separated by the name of cheese. The casein is less digestible in this form than in milk, but nevertheless cheese is a highly nutritious article of diet, and may be employed with great advantage as an addition to daily food. It is difficult to estimate the quantity of food that a human being ought to take in a day. A healthy infant of six months old will consume from one quart to three pints of cows' milk. An average man, weighing one hundred and fifty-four pounds, is found to consume in a day four ounces of flesh formers, twelve ounces of starch, five ounces of butter and fat, two ounces of sugar, and one ounce of mineral matter. This will give a fair idea of the average quantity of solid food required by man. When men work hard they require more food, and persons taking but little exercise require less than those who take a great deal. Growing boys and girls, between twelve and eighteen years of age, require more food than grown-up men and women, as they not only need food to perform the functions of life, but also food to permit of the growth of the various organs of their body.

26. It will be seen that all food must contain *water*. The starch must be made sugar in the mouth to be dissolved in water; the albumens are rendered soluble in water before they are taken up into the circulation; and the fatty matters are converted into soluble soaps by the alkalies of the secretions before they are converted into a part of the body. At least fifty per cent. of solid food, such as meat and bread, is water, whilst, in addition, man drinks in beverages from fifty to one hundred ounces in the day. It is is on this account that it is most important that man should get his water *pure*. Water is usually obtained from rivers or springs, and, under these circumstances, always contains a certain quantity of *organic* and *inorganic* impurities. The latter are derived from the soil and rocks over which or through which the water flows. They consist of the salts of lime, potash, and soda, and when they do not exceed a quantity of from thirty to forty grains in the gallon, are not injurious to health. Water, however, is liable to other inorganic contaminations, more especially in keeping in cisterns, and these, especially the salts of *lead*, should be carefully avoided. When water contains much of the salts of lime, it is called *hard;* and when it contains little or none, as in rain-water, *soft*. Waters containing large quantities of saline matters are called *mineral*. At Bath and Clifton the water comes from its springs in the earth quite hot,

hence it is called *thermal.* The most dangerous contamination of water, however, arises from its *organic* impurities. In river water, the death of its living inhabitants will produce a certain quantity of organic matter. Unfortunately this matter is now too often increased by making use of rivers as common sewers for receiving the refuse of towns and villages on their banks. The sewage of houses and towns not only contains decomposing animal and vegetable matters, but the active germs of fatal diseases. Just as the air is capable of diffusing the poisons of smallpox and scarlet fever, water is capable of disseminating the poisons of typhoid fever and cholera. Thus, these diseases have been propagated by the supply of river water to towns. The great outbreak of cholera in the East of London, in 1866, was traced to the contamination of the water of the River Lea, which supplied that part of London. In the same way spring, well, or pump-water may be contaminated by organic matter leaking into the wells from which it is procured. One of the simplest methods of detecting organic matter in water is to drop into it a solution of permanganate of soda or potash (Condy's Fluid). If the solution retains its colour, the water may be regarded as sufficiently free from organic impurities to permit of its use. If, however, the solution loses its colour rapidly, the water must be regarded as unfit for use as an article of diet. In all doubtful cases water should be boiled or passed through an animal-charcoal filter before it is drunk. Water may be used for washing purposes which might be very injurious if drunk.

CHAPTER III.

ON DIGESTION, AND THE ORGANS BY WHICH IT IS PERFORMED.

27. Before the food of an animal can be appropriated to the use of its body it is submitted to various operations, by which it is fitted to become the means and source of life. In the lowest animals this process is of the simplest kind. Amongst the animacules are creatures which consist merely of a bag or *stomach*, into which the food is carried, and, by a simple process of absorption, the food passes into the structure of the body, and performs all the functions of life; in fact, the lowest animals consist of merely a bag or stomach, into which the food is taken, and the nourishing and vital parts of the food being taken into the surrounding parts, the useless constituents of the food are rejected by the same orifice in which they are taken in. Such is the structure of hydras, sea-anemones, jelly-fishes, polyps, and other low forms of animals. As we ascend in the scale of organisation we meet with animals in which a higher structure is present. The food is received into a bag or stomach, and soaks through from thence into a circulatory system of fine tubes, where it becomes a part of that fluid known as the blood. The food of all animals undergoes certain changes in contact with the oxygen

of the air, which is necessary for their life; and this function, which goes on all over the body in the lower animals, is carried on in special organs in the higher animals. In fact, as we ascend from the lower to the higher animals, we find that particular organs are assigned for the performance of special operations or functions. Thus, the oxidation of the food, which is carried on in every part of sponges, animalcules, and polyps, is performed by *gills* in crabs and lobsters and fishes, and by *lungs* in land-breathing animals and man.

28. In man and the higher animals, the food, before it is converted into blood and applied to the uses of the system, undergoes an elaborate series of changes. It is first taken into the mouth, and that food which which is not liquid undergoes the process of *mastication.* For this purpose the mouth is supplied with *teeth.* These organs have a different structure, according to the food they have to act on. In herbivorous animals the teeth have broad surfaces, as in the sheep, ox, and horse, for the purpose of enabling them to triturate their food before it enters the stomach. These teeth are called *grinders.* Animals such as the lion, the tiger, cats and dogs, which live principally on animal food, have *cutting* teeth, whilst in man, who is destined to live on a mixed diet, the two sorts of teeth are found. The human infant is born without teeth, but at the sixth month they begin to appear, and by the end of the fourth year twenty teeth appear. These are called the milk teeth, and are destined to disappear and make way eventually for thirty-two teeth, which are sometimes not fully developed until the human being has reached the age of from sixteen to twenty-five years. These teeth con-

Plate I.

Fig. 1.

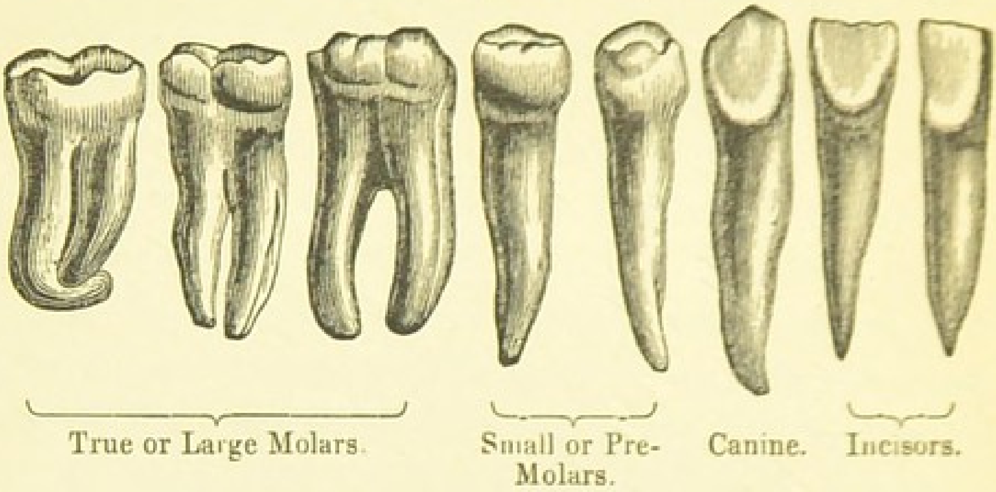


Fig. 3.

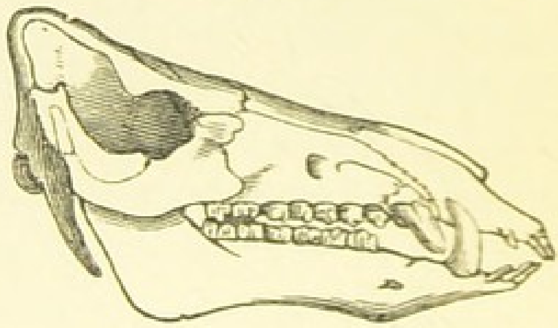


Fig. 2.

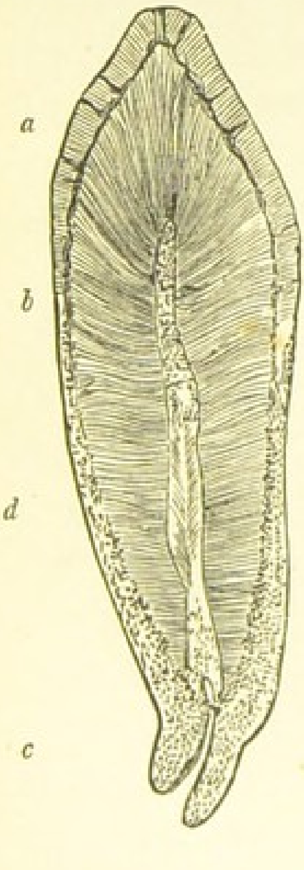


Fig. 4.

EXPLANATION OF PLATE I,

Exhibiting the Structure of the Teeth and Glands of the Mouth, described in paragraphs 28, 29 *and* 77.

Fig. 1.—A set of human teeth. The last five are called molars or grinders. They are divided into large and small molars. The first two are also called pre-molars and the last three true molars. In the human jaw, after the twenty milk teeth are shed, there are eight teeth on each side of both upper and lower jaw like those in the plate. The canine tooth is sometimes called the eye tooth. The incisors are also called gnawing teeth, and are characteristic of rats, mice, rabbits, and squirrels.

Fig. 2.—Section of a canine tooth. *a.* The *enamel* or outside of the tooth, and the hardest structure of the human body, *b.* The *dentine* which constitutes the largest mass of all teeth. It is the same structure as that which produces ivory in the elephant's tusk. *c.* The outside of the fang called *cementum,* and resembling bone in its structure. *d.* The *pulp-cavity* containing the blood-vessels and nerve of the tooth. When the tooth decays and reaches the pulp-cavity where the nerve is, toothache is produced.

Fig. 3.—Diagram of the skull of a boar, showing the three classes of teeth. The canine teeth are very large. The boar has also a larger number of incisor and molar teeth than the human being.

Fig. 4 exhibits the minute structure of one of the glands, called the parotid, situated beneath the lower jaw, and which secretes the saliva or spittle, which lubricates the mouth, and reduces the starch of the food to the condition of sugar. The grape-like cells secrete the saliva which passes along the branching-tubes into the mouth under the tongue. The disease called the mumps arises from inflammation occurring in this gland.

sist of eight teeth in front, like chisels in shape, four in the upper jaw and four in the lower; they are called *incisors.* On each side of these above and below, is a cutting tooth, like those of lions and tigers, called a *canine* tooth. Beyond these, on either side, are five grinding teeth, called *molars*, this making altogether thirty-two teeth. It is between these cutting and grinding teeth that the food is first prepared before being carried into the stomach for digestion.

29. Whilst the process of mastication is being carried on, the food is mixed with a fluid in the mouth, called *saliva* or "spittle." This fluid is exuded from organs, called glands, seated on the sides of the lower jaw, and which empty their contents into the mouth. Saliva is constantly being thrown into the mouth, and the glands which produce it are stimulated to action by substances taken into the mouth. Thus, tobacco smoke stimulates these glands, and engenders in those who smoke the injurious habit of spitting. The saliva contains an active principle, called *salivin*, which, mixing with the starch of food, converts it into sugar (18). The process in which the saliva is so mixed with the food is called *insalivation*, and it is most necessary to healthy digestion that all food containing starch, such as bread, flour puddings, arrowroot, and corn flour, should be thoroughly well insalivated before it is swallowed.

30. When food is masticated and insalivated it is swallowed. This process is technically called *deglutition.* The tongue is employed in this process, and the food having been formed into a lump or bolus by the action of this organ, is transferred to the back of

the throat. Here it is received by a bag, called the *pharynx*, which by its muscular action propels the food down the *gullet* into the *stomach*. This again is a bag, consisting of a muscular coat, capable of acting on and propelling the food like the pharynx and gullet; its interior is lined with a mucous membrane, in which are placed certain glands which have the power of secreting an acid juice, which is called *gastric acid* or *juice*. This juice, like saliva, contains an active principle called *pepsin*, which acts more particularly on the flesh-forming constituents of the food, and converts them from substances incapable of solution in water into soluble substances, called *peptones*. The flesh-forming substances, such as meat, albumen, and casein, are all converted into the same soluble matter, which readily soaks through the wall of the stomach into the blood-vessels. The food in the stomach not dissolved is converted into a pastey mass. This mass moves from one end of the stomach to the other, and passes into the bowels through an orifice called the *pylorus*.

31. The food having passed the pylorus, is subject to the action of two other fluids—one coming from the *liver*, called *bile*, and another from the pancreas, called *pancreatic juice*. These two fluids are poured together into the bowels a few inches below the pylorus. The result of the mixture of these fluids with the pastey mass or *chyme* is the production of a milky liquid matter called *chyle*. It consists of the dissolved sugar and peptone, and minute particles of fatty matter suspended in water. All over the interior of the bowels are a number of minute points called *villi*, like the "pile" on velvet. They

PLATE II.

Fig. 5.

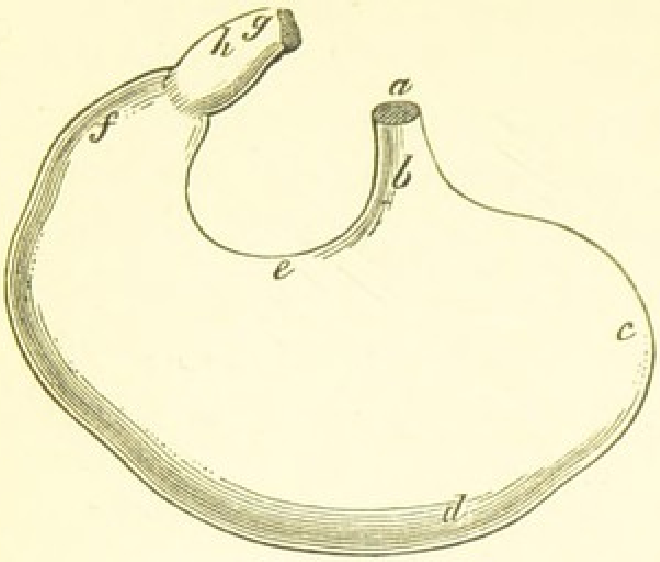


Fig. 6.

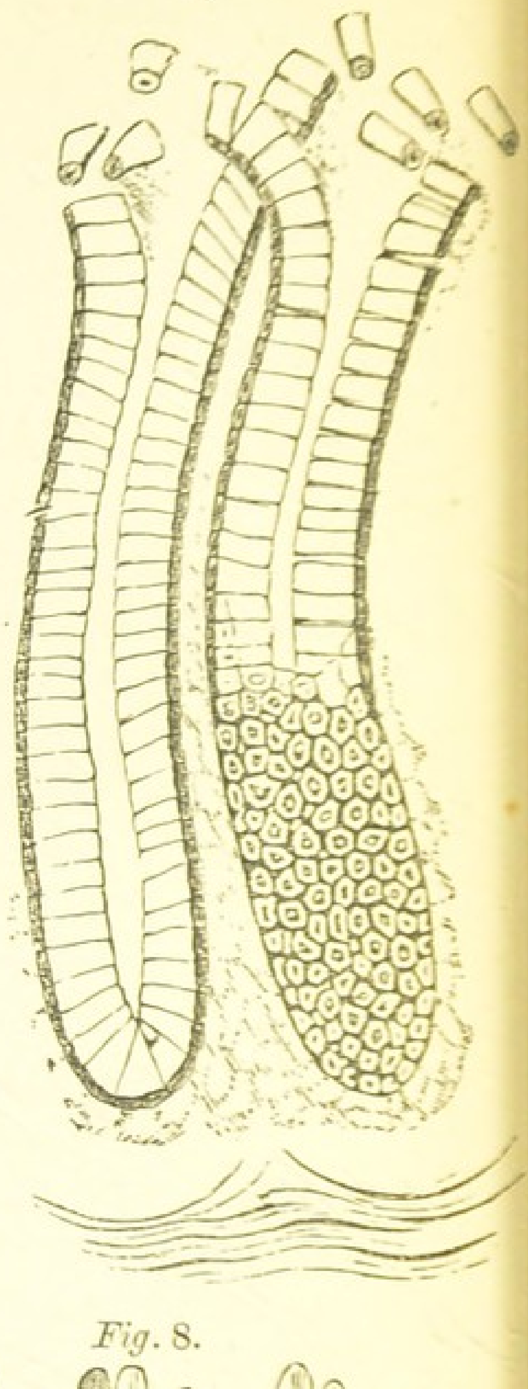


Fig. 7.

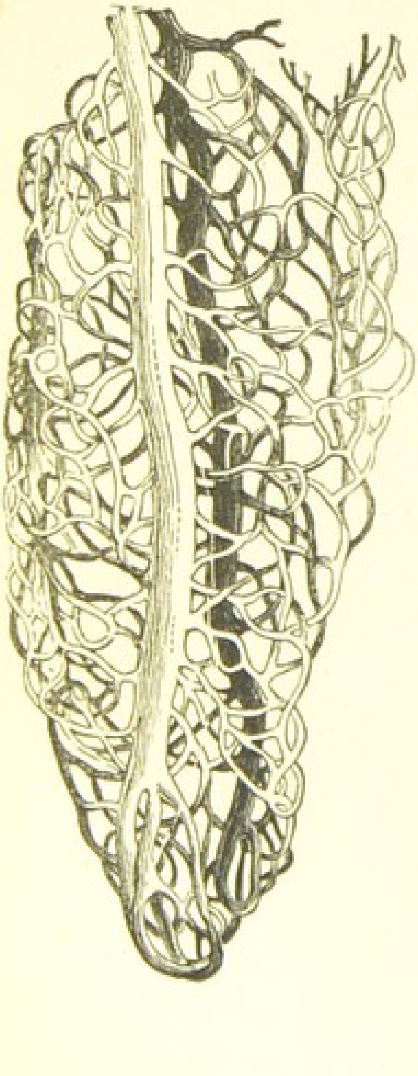
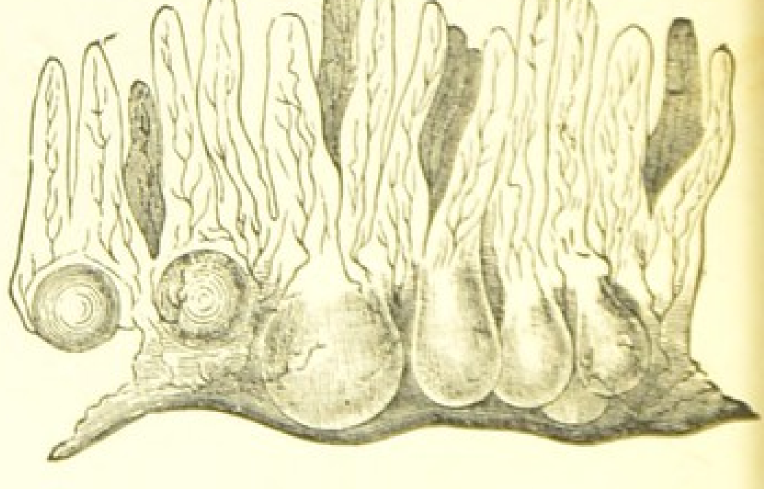


Fig. 8.



EXPLANATION OF PLATE II,

Shewing the Structure of the Digestive Organs, and described in paragraph 30.

FIG. 5.—Diagram of the human stomach.

a. Entrance of the gullet.
b. The cardiac orifice of the stomach.
c. Left border of the stomach.
d. The greater curvature.
e. The lesser curvature.
f. The right border.
g. Commencement of the intestines.
h. The *pylorus*, or pyloric orifice, which is contracted.

FIG. 6 represents two gastric glands. These glands form depressions in the lining of the stomach and the cells with which they are lined are seen. These cells secrete the *gastric juice*, which contains *pepsin*, and effects the digestion of the food. When the food passes into the stomach the cells containing the gastric juice are thrown loose into the stomach, as seen at the top of the diagram. No sooner are these cells cast off than a new set begins to grow.

FIG. 7.—A single *villus* largely magnified to show the network of blood-vessels it contains, and also the tubes which convey the chyle.

FIG. 8.—A cluster of *villi*. It is by means of these organs that the chyle of the blood is absorbed and is carried into the lacteals. The villi are covered over with cells, which absorb the chyle before it is soaked up by the villus.

consist of small blood-vessels and a duct, which last absorbs the fluid chyle, and carries it into a network of minute vessels outside the bowels called *lacteals*, whilst the blood-vessels also soak up some of the liquid. The milky fluid in the lacteals is carried into a larger vessel called the thoracic duct, which empties itself into the blood of the veins in the upper part of the chest very near the heart. In passing from the stomach along the bowels, a large proportion of the liquid contents of the chyle is taken directly into the minute blood-vessels which line the inner membrane of the stomach and bowels, but the blood in these does not go at once to the heart to be sent by it all over the body, but, as we shall see, it has first to pass through the *liver*, where the absorbed food is more thoroughly made into blood. The undigested parts of the food are carried along the bowels and are ultimately rejected.

32. The ultimate object of the function of digestion is the preparation of the food for being absorbed and converted into blood. Although amongst the lower animals, little or no preparation of the food before being masticated is found necessary, it is owing to the characteristics of man that he is a "cooking animal," and that previous to eating it, he submits a large proportion of his food to heat. This is found to aid greatly in the process of digestion, amd facilitates the conversion of food into blood. Food is cooked either by placing it in contact with heated air or heated water. The former process is called *baking* or *roasting*, the latter *boiling*. Animal and vegetable foods are submitted to either of these processes. Wheaten flour is mixed with water, and then fermented

with yeast and submitted to heat, and is then called *leavened* bread. When flour is not fermented, biscuits of various kinds are produced and form *unleavened* bread. By the process of leavening, the bread is vesiculated by the particles of carbonic acid gas, produced by the leaven, and it is thus made *light* and is more easily digested than unleavened biscuits. Bread is sometimes made light by pumping into it atmospheric air, which vesiculates it in the same way as yeast, and it is then called "aërated" bread.

33. Animal food is also baked and roasted; by this means the little cells and fibres of which animal flesh is composed are broken up, and they are more readily digested than raw meat would be. In baking or roasting, care should be taken to expose the meat to a strong heat at once; this has the effect of coagulating the albumen which is contained in the meat, and which thus forms a kind of impermeable case round the baking or roasting meat, and prevents the juice from the interior of the meat from running away. This juice contains the flavouring matter of the meat, as well as other chemical compounds which, acting on the mouth and stomach, influence beneficially the process of digestion. It is on this account that small quantities of animal food are better than none, and act more advantageously than equivalent quantities of vegetable food.

34. In boiling animal food, the same principle should be recognised as in baking or roasting. The animal or joint should be first placed in boiling water till a case of coagulated albumen is formed outside. When this is formed, the heat may be reduced and the meat cooked at a somewhat lower

temperature. In all cases where animal food is boiled, it should be recollected that certain quantities of the flavouring and saline principles of the meat are dissolved in the water. These may be made available for food by converting the water thus employed into soup. The use of soup as an article of diet is much neglected. Many portions of animal food which cannot be served up separately, may be made into soup which, thickened with the flour of wheat, barley, oats, peas, lentils, maize, rice, or potatoes, and flavoured with condiments (22), form excellent food. All articles of diet containing starch are thickened or even made solid by boiling. Thus flour and water are mixed and made into a paste, which, by boiling, become converted into "dumplings." Eggs mixed with flour and various other things, form "puddings" by the process of boiling.

35. It is very desirable that all cooked food should be taken hot. When cold food is taken it reduces the temperature of the stomach, and both the nerves and vessels of the stomach are taxed in order to bring the temperature of the food thus taken up to that of the human body. Mankind in all ages seems to have discovered that it is desirable to prevent this tax upon the internal organs, and have taken their food hot in order to prevent it. It was death to the Roman slave to bring in his master's water tepid or cold, so much importance did they attach to hot water as drink. We drink tea, coffee, and chocolate hot, and these substances are added to water in order to flavour it which is a necessity of the system. It should, then, be recollected that a hot meal is a great economy compared with a cold one, and that, as a rule

of life, it is better to consume food hot rather than cold. It is only in very hot weather in temperate climates, or in tropical climates, that food can be taken with advantage when cold, or that ice and iced drinks can be taken with impunity.

36. Not only should food be properly prepared before it is eaten, but it should be taken at proper times. Vegetable food requires a longer time to digest than animal food, and herbivorous animals take larger quantities of food and are longer in digesting it than carnivorous animals. Man is an omnivorous animal, and whilst he can exist either entirely on animal food, or on vegetable products only, he undoubtedly flourishes best on a mixed diet. An examination, also, of the structure of his teeth, stomach, and bowels show that he is adapted to take a mixture of animal and vegetable food. Under these circumstances man is found taking his meals several times a day, and there is no doubt that he digests his food better by taking it twice than once a day, and three times better than twice. It seems a most natural arrangement that he should take breakfast, dinner, and supper. Breakfast should be taken from half an hour to an hour after rising. Dinner or luncheon four or five hours after breakfast, and supper or dinner five or six hours after the middle-day meal. It is never well to protract the last meal to within a short time of going to bed. A full stomach interferes with the action of the heart, and blood-vessels, and lungs, when the body is in a horizontal position. Time should also be given to the taking of food, and meals should be taken sitting, and at least half-an-hour should be given to each meal.

Plate III.

Fig. 9.

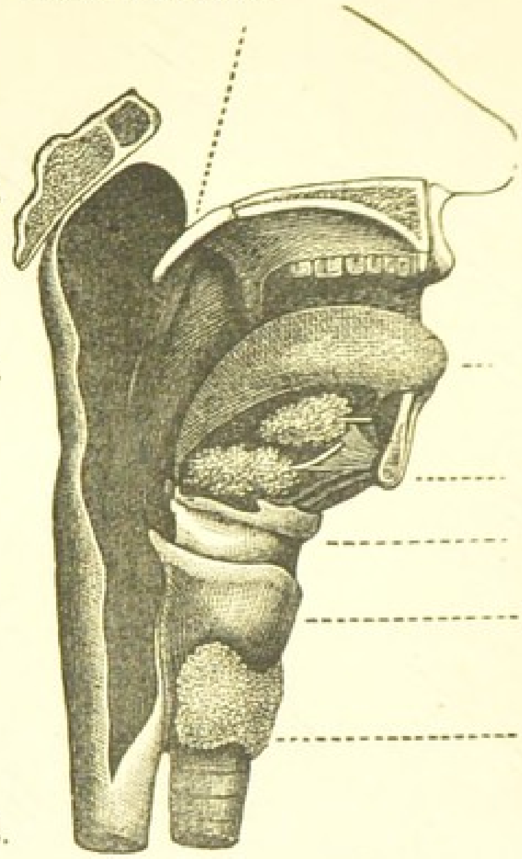
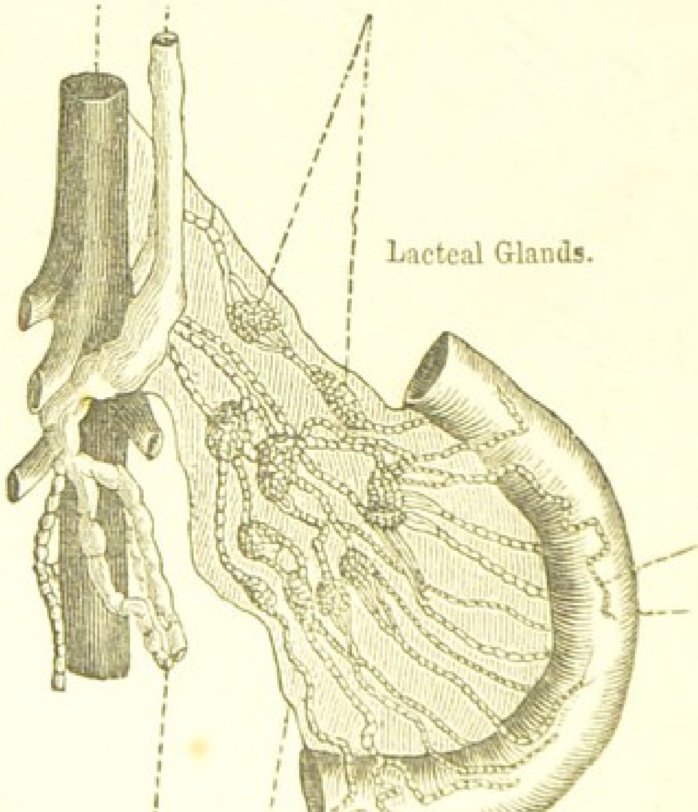


Fig. 10.



EXPLANATION OF PLATE III,

Showing the Relative Position of some of the Organs of Digestion, Respiration, and Circulation, referred to in paragraphs 28, 29, 30, 31, *and* 37.

FIG. 9 shows the arrangement and relations of the organs of digestion and respiration. The teeth of the upper jaw are seen in section, and the tongue leading to the bag at the upper part of the gullet, called the pharynx; the gullet is seen leading down into the stomach which is seen in Plate II. Under the tongue lie the salivary glands, an enlarged view of which is seen in Plate I. In front of the pharynx is the larynx, which contains the organ of voice. In front of the larynx is the thyroid gland, and, leading into the lungs, is the trachea or wind-pipe.

FIG. 10 shows the lacteal or mesenteric glands, with the lacteals which convey the chyle from the intestines to the large duct called the *thoracic canal.* The latter is seen lying close to the aorta, the great blood-vessel which carries the blood from the heart to all parts of the body. The thoracic duct empties its contents into the blood through the large veins of the neck.

CHAPTER IV.

ON THE NATURE OF THE BLOOD, AND ITS CIRCULATION BY THE HEART.

37. The food, after being dissolved, is taken up into the blood-vessels, either directly or through the lacteals, and is the great means of the renewal of the blood. This, however, is not the only fluid which enters the blood, and serves for its production. Throughout the whole body there exists, besides the fine network of blood-vessels, a network of minute vessels, called *lymphatics*, and which join the *thoracic duct* like the lacteals. They contain a clear fluid, which is called *lymph*, and is derived from the various parts of the body to which these vessels are distributed. Just as the blood-vessels and lacteals of the bowels take up the liquid food, so do the lymphatics and the blood-vessels in muscles and nerves and bones take up the liquids which these turn into as they die and waste away, in doing their work. In the lower animals the blood is generally free from colour, like lymph; but as we ascend in the scale of organisation the blood gradually becomes opaque, and in fishes, reptiles, birds, the mammalia, and man, it is red.

38. The blood of man, when drawn and looked at with the naked eye, is a red liquid. When allowed to stand for a few minutes it "coagulates," and is

separated into two parts—a solid part, which is called *clot*, and a liquid part, in which the clot floats, and which is called *serum*. If a drop of blood is placed under a microscope before it coagulates it is found to consist of two parts—a liquid, called "*liquor sanguinis*," and a number of small flattened globules or cells, which are called *blood globules*. The latter are of two kinds, red and white. The white globules are rounder, rougher, and larger than the red ones; they differ further in containing a more solid central part or kernel, and do not form more than one in a hundred of the blood-globules altogether, though the lymph is full of them. Their "kernels" or *nuclei* are supposed to escape and become red globules. The red globules are very minute, and when measured are found to be $\frac{1}{3500}$th of an inch in diameter: that is, 3500 of these minute bodies could be placed side by side on a single linear inch. These red globules are depressed both above and below, and in man and those animals which suckle their young, have no kernel; but in birds and reptiles and fishes they have one. The red globules are composed of a red substance called *hæmoglobin*, which can be separated into an albumen called globulin, and a colouring matter, which gives the thin red colour, and is called *hæmatin*. The size and shape of the blood-globules varies in different animals. In sheep, oxen, and deer, they are smaller than in man, and are much larger in reptiles; they are oval in birds and fishes. A knowledge of the forms of the blood-globules has sometimes led to the detection of crime by revealing the exact nature of blood-stains found upon clothes after the commission of crime.

Plate IV.

Fig. 11.

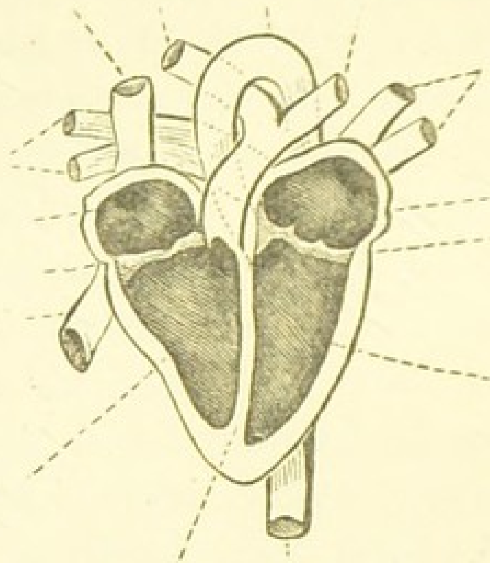
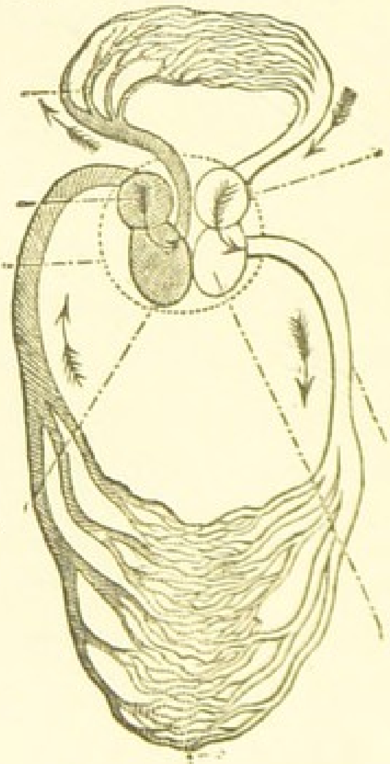


Fig. 12.



EXPLANATION OF PLATE IV,

Representing the Structure of the Heart and the Passage of the Blood through the Lungs, and referred to in paragraphs 40, 41, 42, 43, 44, *and* 45.

FIG. 11 represents a section of the heart. It will be seen that there are four cavities, two on the right side and two on the left. The upper two are called auricles, and the lower two ventricles. The right auricle receives the blood from the great upper vein (*vena cava descendens)*, and from the great lower vein (*vena cava ascendens*). The right auricle sends its blood through the tricuspid valve into the right ventricle, from whence it is carried by the pulmonary arteries to the lungs, and then, aerated, it returns to the left auricle of the heart, passes through the mitral valve into the left ventricle, from whence it is projected into the aorta to be sent to the whole of the body.

FIG. 12 is a diagram of the circulation of the blood in the whole of the body. In this diagram the circulation of the blood through the capillaries of the lungs and of the whole of the body is represented. There is one thing to be noticed here, and that is that the pulmonary arteries carry venous blood whilst the pulmonary veins carry arterial blood. The distinction between an artery and a vein is not that the one carries arterial and the other venous blood, but that the artery carries blood from the larger to the smaller parts of the vessel, whilst the vein carries blood from the smaller to the larger parts of its tube. It will be seen from these diagrams that the ventricles have thick walls and are more powerful organs than the auricles as they have more work to do.

39. The liquor sanguinis consists of water, albumens, and saline matters. When blood coagulates, an albuminous body which has been called blood-fibrin is formed, and separates, entangling the blood-globules, and constitutes the clot. The serum which is left holds in solution most of the albumens and saline matters. The serum also contains various other matters, such as colouring and odoriferous principles, with dissolved fatty matters. The proportions of these substances in 100 parts of dead blood is as follows:—Water 79 parts, albumens 4, globules 14, fibrin $\frac{1}{5}$, and the salts and other principles $2\frac{4}{5}$. It also contains oxygen and nitrogen gases, carbonic acid and a little ammonia. Thus constituted, it is carried by means of the heart and arteries to all parts of the body. On coming in contact with the delicate structures of the body it supplies them with new materials by which they perform their various functions, and carries away those particles which have done their duty in the work of life. In its course through the body it is carried to various glands, which separate from it those compounds which are to be thrown off from the body. Whilst in the lungs, it takes up oxygen gas, but throws off carbonic acid gas, which is injurious to the body. In the liver it gets rid of certain products which form the bile, and which appear to be again taken up into the blood in the bowels. In the kidneys it gets rid of a substance called *urea*, which, like the albumens, is formed of all four of the organic elements, and represents these substances in a changed and effete form, by which they are thrown out from the body.

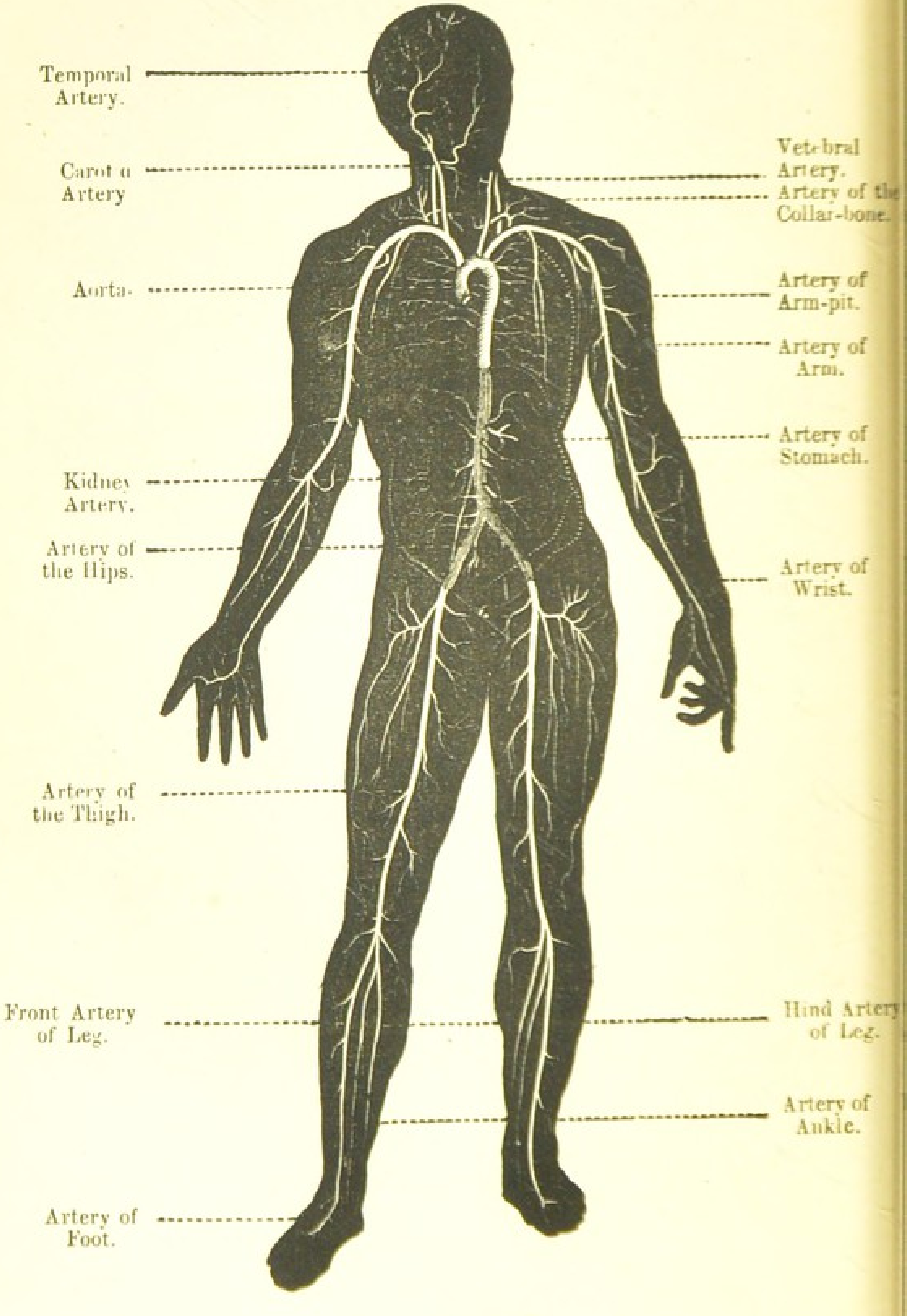
40. The organs by which the blood is carried all

through the body are called a circulatory system. In the lower animals this system consists of a simple open vessel, situated between the stomach and skin, which contains an uncoloured fluid, the result of the direct conversion of the food into a nutritious material. In insects, this simple vessel presents certain dilatations, which expand and contract, and send the fluid blood through all parts of the body. Passing upwards, through fishes and reptiles, these bags become more complicated in their structure, and form what is called *a heart.* In birds, the mammalia, and man, the heart consists of four cavities, which are all bound together to form one organ, called a heart. The structure of this organ can be best understood by taking the heart of a sheep or bullock, and cutting it up with a pair of scissors, when the four cavities can be easily discerned.

41. The heart in the higher animals and man is divided into a right and left side, or a right and left heart. Each of these has two cavities. One of these cavities is called an auricle, the other a ventricle. They are all composed of muscular fibres, which are so arranged that when the muscles contract the cavities become shrunk, and the blood which they contain is pressed out of them. The auricles are thinner and less powerful than the ventricles, and the ventricle of the right side is of less size and weaker than on the left. In man, the heart is placed a very little to the left of the thorax, and its pulsations may easily be heard by placing the ear on the left side of the chest. The right auricle receives into it the blood which flows along the great veins from the head and lower parts of the body. The blood

VI.

Fig. 15.—THE BLOOD VESSELS.



EXPLANATION OF PLATE VI,

Exhibiting the Arterial System in Man. A description of the structure and functions of the arteries is given in paragraph 42.

In the diagram all the other organs are removed in order to show the whole arterial system. The blood which passes along the arteries is pumped into them by the left ventricle. It first passes into the aorta through the arch which is seen in the diagram. The arch of the aorta before it descends gives off the arteries leading to the right and left arms, and also the carotid arteries which pass into the skull and supply the brain with blood. The aorta then passes into the chest and abdomen and gives off arterial branches in its course, the most important of which are those which go to the chest, to the stomach, the liver, the kidnies, and the organs in the pelvis. In the pelvis the aorta bifurcates and sends down branches which supply blood in the pelvis and the *femoral* arteries, which pass down the front of the thigh, and divide again to supply the legs. The arteries terminate in minute branches, which form the capillaries uniting in all parts of the system the arterial and venous systems. The veins in returning the blood to the heart take almost the same course as the arteries, but the veins are situated more superficially than the arteries and are easily seen through the skin on the surface of the body.

having flowed into the auricle it contracts, and forces the blood into the ventricle. The ventricle contracting, propels the blood through the large blood-vessels called the pulmonary arteries, through which it passes into the lungs. The right side of the heart is hence called the *pulmonic* heart, because it forces the blood into the lungs. Whilst passing through the lungs, the blood is exposed to the action of the atmospheric air, and becomes changed in colour from a dark colour to a bright red. The dark blood is called *venous* blood, as it has been brought to the lungs from the veins; the bright red blood is called *arterial* blood, as it passes from the lungs to the left heart, and is thence distributed by this organ through blood-vessels called arteries to the whole of the body. The left heart is hence called the *systemic* heart. The blood passes from the lungs by the pulmonary veins to the left auricle of the heart, which, when the blood arrives, contracts and sends it into the left ventricle; from this cavity, which is the strongest and most powerful of all the cavities of the heart, it is sent into the great aorta, a large blood-vessel which runs first upwards, then curves round and runs straight down along the interior of the body, giving off in its course numerous branches, by which the living stream of the blood is conveyed to all parts of the body.

42. The blood is carried by the aorta and its branches to the head, to the arms, to the stomach and bowels, to the liver and kidneys, to the legs, and all other parts of the body. It courses along blood-vessels, all of which are called *arteries*. These blood-vessels are seated deeply in the textures of the body, and are composed of an elastic fibrous

membrane, which yields to each separate impulse of the heart, and which, in some places, as in the neck, can be seen with the eye, and in some parts can be felt with the finger. The beating of the arteries, produced by the contraction of the heart on the blood, is called the *pulse.* When the ear is applied to the chest over the region of the heart, two sounds are heard, the first, a longer and duller sound than the second, which is sharp and short. These sounds result from the quick movement of flaps of membrane inside the heart, which are pressed against by the blood when the heart contracts, and so prevent it from going the wrong way. The pulse is the result of the contractions of the heart, and equals them in number. The pulse varies much in frequency, according to age, health, and other circumstances. Seventy beats in a minute may be regarded as the ordinary number of a healthy man. It is much quicker in infants and children, and slower in old age. It is quicker in women than in men, and beats more frequently in an erect position than in lying down, and is more rapid during exercise than when persons are resting.

43. The arteries terminate in delicate networks of small blood-vessels, called *capillaries.* They are called so from their resembling a hair (*capilla*). They are, however, finer than any hairs, varying from the five thousandth to the fifteen hundredth part of an inch in diameter. Between these capillaries, which are looped together and form a network, are minute interspaces, consisting of the various textures of the body. The walls of the capillaries are so thin and soft, that they admit of the fluid parts of the blood

soaking through them, and thus a perfect communication exists between them and the textures of the body in which they are placed. The arteries then, coming *from* the *left* side of the heart, terminate in capillary vessels, and it is through these that the blood passes to that set of vessels which go *back* to the *right* side of the heart, and are called the veins. In the capillary vessels the chief work of the blood is done. It is here, as we have seen, that those intercharges between the blood and the tissues take place, which are necessary for the nourishment of the body and the carrying on of the various functions of life. In these minute vessels those changes take place which result in what is called "inflammation," and it is from the unhealthy action of the capillaries that those deposits are made in the tissues which result in some of the most fatal diseases to which human beings are subject. Some of these diseases are familiarly known as cancer, scrofula, and tubercles of the lungs, or consumption. The blood coming from the left side of the heart contains more oxygen than that going to the right. It is during its passage through the capillaries of the body that it loses a portion of its oxygen, which is used up in "oxidizing" the tissues.

44. The blood, having passed through the capillaries, goes to the veins, and from them is conveyed to the right side of the heart. The coats of the veins are thinner than the arteries, and, when empty, they collapse, but an artery remains tubular after it has been emptied of its contents. The veins are usually placed on the surface of the body, and can be seen carrying the dark blood on the backs of the hands, on

the arm, and in the neck. The veins, in carrying up the blood from the lower parts of the body, have a difficult task to perform; and when their internal structure is examined, it is found that they are assisted in this work by a series of *valves*. These valves are placed directly across the veins, and allow the blood to go onwards, but prevent its going back; they act, in fact, like ordinary flood-gates, which allow the water to go through in one direction, but shut when it attempts to flow the other way. It was the observation of these valves that led Harvey to the discovery of the circulation of the blood. He felt sure that the blood must go on in the veins into the heart; and although he never saw it passing through either the capillaries of the lungs, or the system, he felt himself justified in asserting that the blood passes constantly from one side of the heart, round by the body or lungs, to the other. By the aid of a microscope, every one can now see what Harvey never witnessed, and that is the passage of the blood-globules through the capillaries. This may be easily seen by placing the web of a frog's foot or the tail of a tadpole under the object-glass of any good microscope.

45. A word must now be said about the "valves of the heart," those flaps of membrane which we mentioned just now as causing the "sounds" by their movement. The veins of the head and those of the body run each into very large veins, called *venæ cavæ*, of which there are two, one running upwards, and the other downwards. These unite very near the heart, and open into the right auricle. Through this auricle the blood flows into the right ventricle, which becomes nearly full of blood, and is quite filled by the contrac-

PLATE V.

Fig. 13.

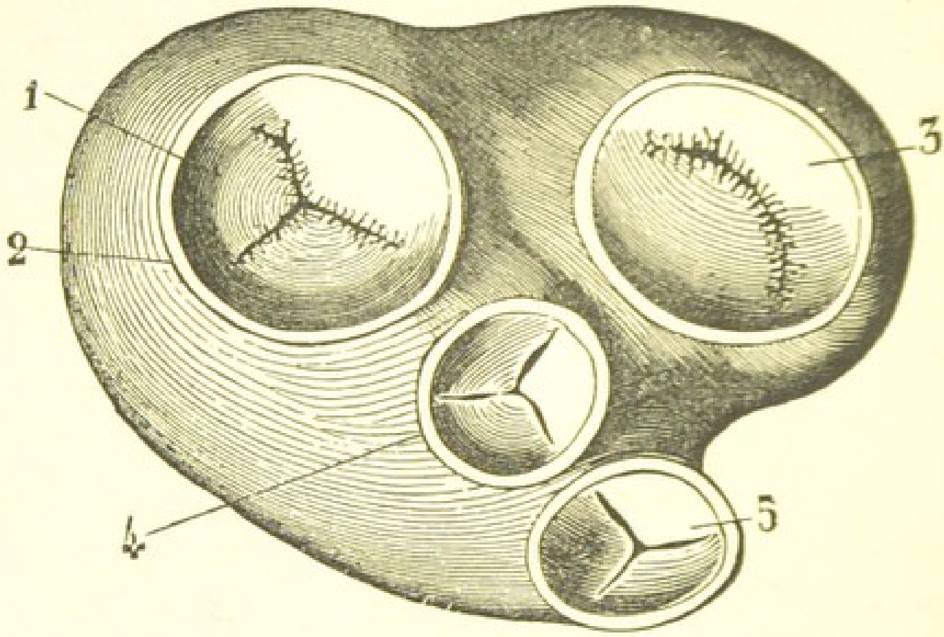
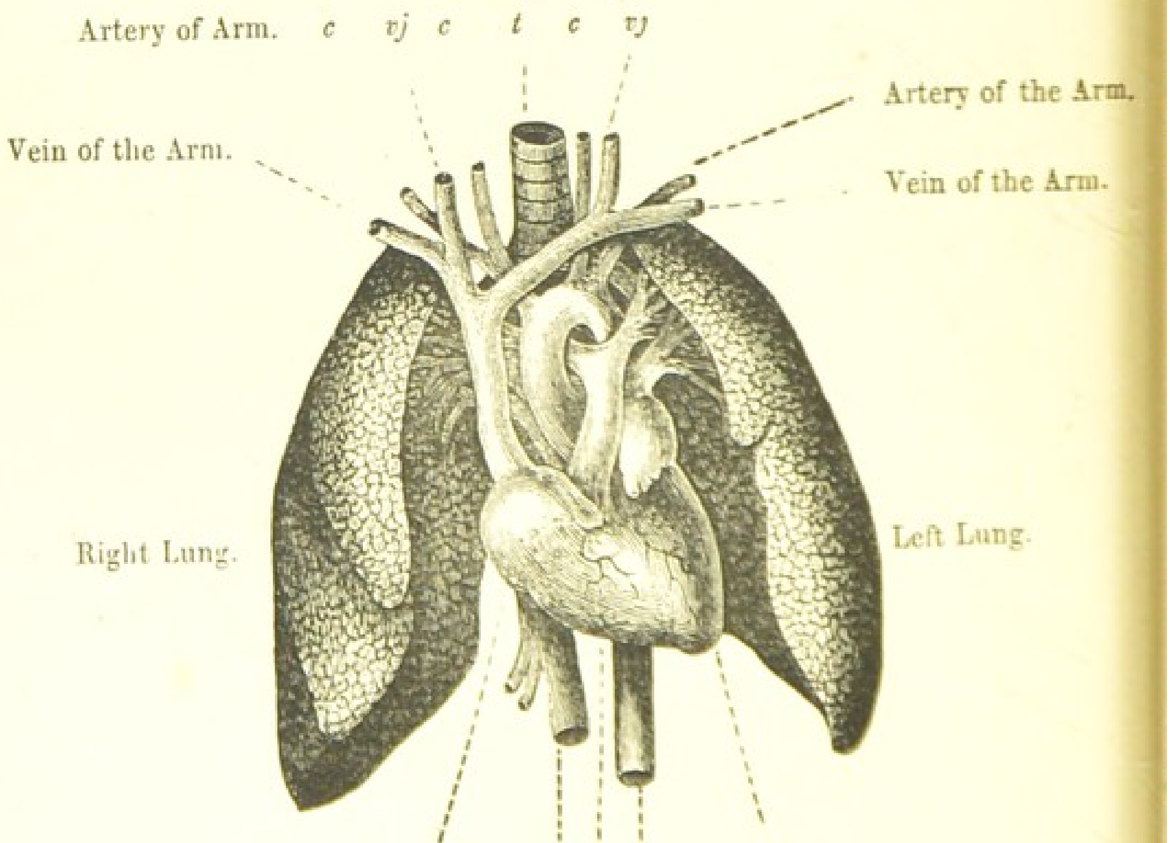


Fig. 14.



EXPLANATION OF PLATE V,

Shewing the Valves of the Heart and the relation of the Heart and Lungs; the subjects of these illustrations are more particularly referred to in paragraphs 45 and 48.

FIG. 13 shows a section of the upper surface of the heart, the auricles on each side having been cut away. 1 and 2 show the tricuspid valve which is the valve that closes to prevent the blood from the right ventricle going back into the right auricle when it contracts. 3, is the mitral valve closed, and which prevents the blood from passing from the left ventricle into the left auricle. At the commencement of the pulmonary artery and the aorta are valves called semilunar or half-moon shaped valves, which being pressed upon by the blood as it goes forward, closes the valves and prevents the blood from going back. There are no such valves in the venæ cavæ or pulmonary veins, as the blood flows with great ease from these veins into the right and left auricles. The valves of the heart are very liable to diseases which prevent their closing completely, and then serious derangements of the whole circulation occur.

FIG. 14 shows the relative position of the heart, great vessels, and lungs in the human chest. *vj*, *vj*, are the two jugular veins which carry the blood from the head to the right side of the heart. The veins of the arm are also marked, bringing up the blood from the arms. *vc* is the great vein (*vena cava ascendens*) bringing up the blood from the trunk and legs; *od* is the right auricle; *vg*, the left ventricle; *a* is the great aorta which carries the blood to all parts of the body; and *c*, *c*, *c*, are the carotid arteries proceeding from the arch of the aorta and carrying the blood to the head.

tion of the auricle which then occurs. As soon as this happens, three flaps which are placed between the auricle and ventricle are pressed out by the blood, and so stop its going back into the auricle. Then the ventricle contracts, and forces the blood into the pulmonary artery, at the entrance to which are three more flaps, which prevent the blood from getting back into the ventricle after it has once been squeezed out. Just the same thing happens on the left side of the heart with the blood coming in from the lungs, but the valve between the left auricle and ventricle has only two flaps. The right auriculo-ventricular valve is called the "*tricuspid*," from its three long flaps; the left auriculo-ventricular valve is called the "*mitral*," and is the strongest in the heart; it gets its name from resembling somewhat a bishop's mitre. The valves at the entrance of the arteries are called the "*semilunar* valves." The contractions of the heart are, as we can feel, very quick and sudden, and so are the movements of the valves. The two auricles move at the same time, and then immediately the two ventricles. The first sound is caused by the tricuspid and mitral valves; the second (short and quick) by the semilunar valves. It will be seen that the most delicate part of the structures entering into the organs of the circulation are the valves. If these valves refuse to perform their duty, a disturbance of the circulation ensues. Various defects of the valves of the heart have been recognised by medical men, and all are attended with serious consequences to life. These defects of the valves can be detected by applying the ear to the chest, as they are always accompanied by a modification of the healthy sounds of the heart.

46. Although the veins generally carry the dark-red blood that has been used in the capillaries directly to the heart, there is one notable exception, and that is in the case of the veins that supply the stomach and bowels. These veins, instead of carrying their blood into the great vein which goes direct to the heart, form a network in the *liver* (31). The vein which carries this blood into the liver is called the portal vein; and when it penetrates the liver it divides into minute branches, which are surrounded by fine tubes called gall- or bile-ducts, which lead into one large duct, and thus into the bowels. It is from the contents of the portal vein that the bile is formed, and passes into the gall-ducts. But besides this separation of bile from the blood, the liver changes it in other ways; a body like starch (called *glycogen*) is separated from it, and the absorbed food is made more thoroughly into blood; blood-globules also are made here. The *spleen*, *thyroid* gland, and *lymphatic* glands, are bodies (the latter scattered all over the body) through which the blood passes, and in which it is changed, more or less, but nothing is taken *out* of it. In the spleen, blood-globules are formed in great numbers.

CHAPTER V.

ON BREATHING, OR THE FUNCTION OF RESPIRATION.

47. In all animals the food which is destined to become a part of their bodies is exposed to the action of the atmosphere. Enveloping the whole earth, and extending forty miles in height, is the atmosphere in which we all live. It is composed of two gases, oxygen and nitrogen. In 100 parts it consists of twenty-one of oxygen, and seventy-nine of nitrogen (4, 5). The oxygen is the agent which is necessary for life. The nitrogen acts as a means of allaying the activity of oxygen. It is the oxygen which acts in the animal body; and by means of its chemical action on the food or the blood is essential to the support of life. Although the larger number of the lower animals live in water, it is the air dissolved in the water that supports their life. If we drive off the air from water by boiling, and when it is cold put into it water-animals, they die for want of oxygen. In the lowest animals, as the animalcules and polyps, the whole surface of their bodies is exposed to the action of the oxygen; but as we ascend in the scale of being, we arrive at animals with special organs in which the blood is *aërated*, or exposed to the action of oxygen. Those organs in the lower animals and fishes are called *branchiæ* or gills. They consist of delicate membranes,

abundantly supplied with capillaries; and as the blood passes through them, their very thin walls allow the air dissolved in the water to make its way into them, and the blood in them is thus aërated or oxygenated. The result of this process is that the oxygen is taken by the blood into the whole of the body, and, meeting with carbon, which is contained in the food, unites it with it, and forms carbonic acid gas, which is given off in the gills at the same time that the oxygen is taken in. The same process goes on in air-breathing animals. In these, instead of gills, we have sacs or bags, which in the higher animals are called *lungs.* The atmospheric air, being taken into the lungs, is absorbed by the blood, and carried by it into the tissues, where it unites with the carbon of used-up parts, and carbonic acid is formed. This carbonic acid is thrown out of the blood in the lungs at the same time that the oxygen is taken in. This process is called *respiration.*

48. The air of the atmosphere is taken into the human lungs by means of the mouth and nose. The nose, however, is the natural passage which leads to the *windpipe;* this is an open tube which leads down into the lungs. When the windpipe or *trachea* reaches the lungs, it divides into two great branches, one of which goes to the right lung, the other to the left. These branches are called *bronchi*, hence the word *bronchitis*, which is used to signify an inflamed condition of these organs. The bronchi go on dividing and sub-dividing, till they terminate in little cells, called *pulmonary sacs.* On the walls of these sacs the capillaries, which come from the pulmonary arteries on the one side of the lungs, and go to the pulmonary veins on the other, are spread out. It is

Plate VII.

Fig. 16.

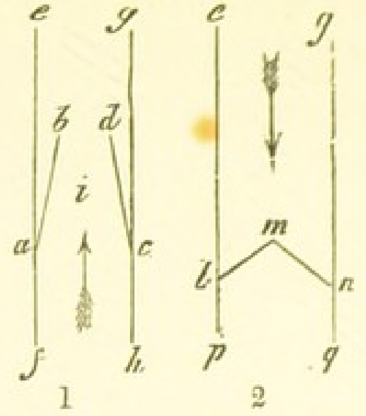


Fig. 18.

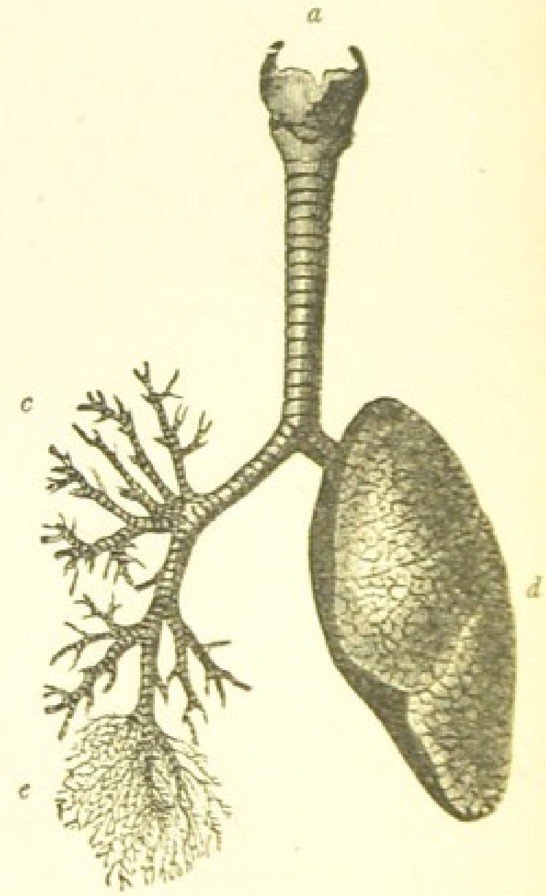


Fig. 17.

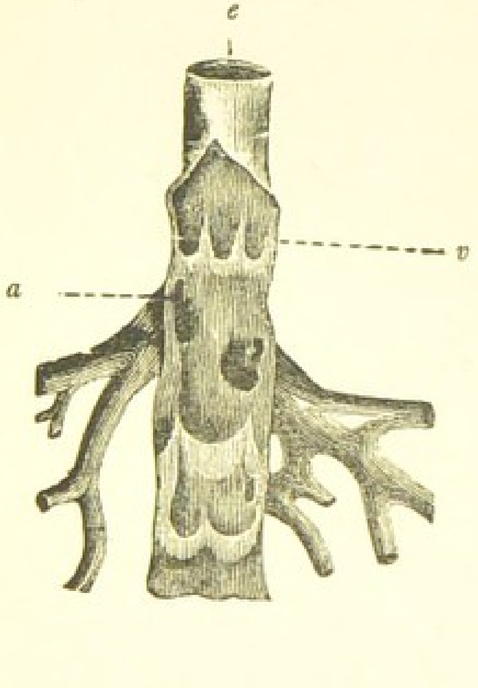
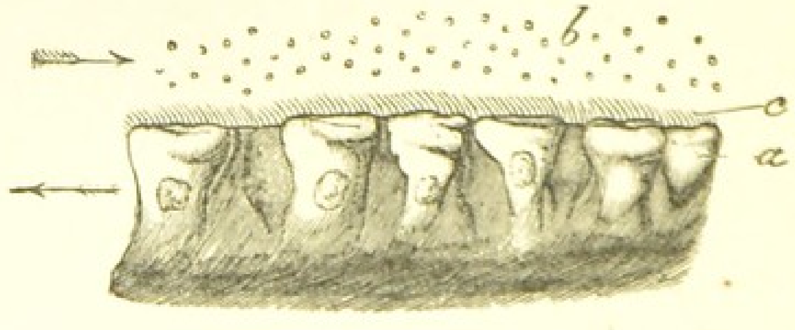


Fig. 19.



EXPLANATION OF PLATE VII,

Exhibiting the Structure of the Veins, also the Air Passages of the Lungs. These organs are referred to in paragraphs 44, 48, 49, *and* 50.

FIG. 16 is a diagram illustrating the action of the valves of the veins. 1 is a vein with the valves of the vein open so as to allow of the blood passing upwards in the direction of the heart. The arrow indicates the course of the blood; *a b* and *c d* represent the valves; *e f* and *g h* the sides or walls of the veins; and *i* is the channel through which the blood flows. 2 represents a vein with the valves closed; *e p* and *g q* are the walls of the vein; and *b m* and *n m* are the valves which are now seen to be closed. It will be seen that the current of blood passing in the direction of the arrow cannot pass back to the lower or smaller parts of the vein.

FIG. 17. A vein laid open so as to exhibit the valves of the heart in their natural position. *e* is the end nearest the heart; *v* is one of the valves; *a* the aperture of a vein.

FIG. 18. The lungs and windpipe of man. *a* is the larynx at the top of the windpipe; *b* is the windpipe which is seen to be composed of a series of cartilagenous rings which are bound together by a fibrous membrane; *c* and *e* represents the lung with the soft tissue and blood-vessels removed; *c* are the larger air passages or *bronchi*; *e* are the smaller bronchi which terminate in minute sacs which are called the air cells or pulmonary sacs; *d* represents the left lung in its natural state.

FIG. 19 represents a magnified portion of the lining membrane of the windpipe. This membrane is covered with column-like cells which have a nucleus in their centre and are covered with cilia (¶ 86). It is by means of these cilia, which are constantly in motion, that the membrane of the lungs is kept free from the deposit of substances that would be injurious. *a*, the columnar cells; *b*, particles of matter moved by the cilia; *c*, the cilia. The arrows indicate the direction of the currents.

in these little sacs that the great work of respiration is performed. The oxygen of the air penetrates the walls of the capillaries, and is absorbed by the blood they contain. At the same time a converse change takes place with regard to the carbonic acid gas which is present in the blood. This gas passes out of the capillary vessels into the air-sacs, and from there spreads itself into the bronchi, and is then squeezed out in the air. Every time we draw in a breath or *inspire*, we take in a fresh quantity of atmospheric air, containing oxygen and nitrogen. Every time we give out a breath or *expire*, we throw off from our lungs carbonic acid gas and nitrogen. This last gas penetrates the blood but little, and goes in and out of the lungs without change. The breath is by no means all carbonic acid gas. It has gained only 8 volumes in 100 of this gas in place of an equal volume of oxygen.

49. The mechanism of respiration is very interesting. The air does not pass into the lungs by virtue of a strong muscular effort, but it passes into it just as it does into a bellows. During expiration the lungs are emptied by compression, and the lungs are filled again by their distension. The process by which the lungs are emptied and filled, is principally effected by the agency of a large muscle, called the *diaphragm*. This is attached to the sides of the ribs, and divides what is called the *chest*, which contains the lungs and heart, from the *abdomen*, which contains the stomach, liver, bowels, and other organs. During respiration the fibres of this muscle contract and relax, and it consequently falls and rises. During inspiration it falls and makes way for the lungs to expand, and it is during this falling of the diaphragm that the

air rushes into the expanding lungs, just as air rushes into a pair of bellows. Sometimes an interruption takes place to the regular expansion and contraction of the diaphragm, and a kind of spasm takes place which is known by the name of *hiccough*. When any irritating substance is applied to the nostrils, an expulsion of the air from the lungs takes place, and the act is called *sneezing*. *Yawning* is a series of deep inspirations and expirations. *Coughing* is produced by some irritation in the bronchi—thus, an accumulation of the natural secretion of the bronchi, produces cough. Some of these actions are seen in a common cold, which commences with sneezing from irritation of the mucous membrane of the nostrils, and ends with coughing as the irritation extends to the bronchi.

50. The air passes to and from the lungs about fifteen or sixteen times in the minute; the rush made by the passing air in the bronchi can be distinctly heard by placing the ear on the chest. The sounds thus heard are called breath sounds, and they are modified by various diseased conditions of the lungs. When the mucus accumulates in the bronchi, the air passes through the liquid mucus and makes all sorts of curious noises, which are called *râles* or rattles. Thus there is a râle like the snoring of a pig, another like the cooing of a dove, others like nests of small birds or like the sound of striking on a cracked mug. The state of the lungs may also be detected by striking the chest with the tips of the fingers or a small hammer. Naturally, the lungs are resonant and sound hollow like a drum, but in some diseases, such as inflammation of the air sacs, or consumption, the lungs

Plate VIII.

Fig. 20.

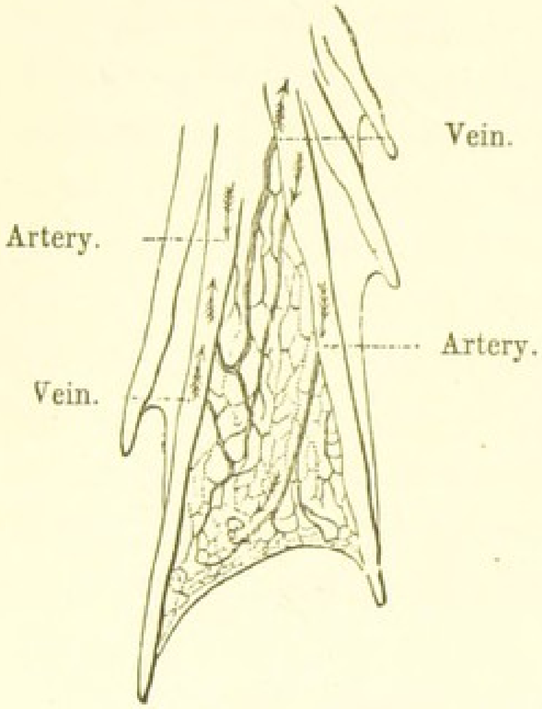


Fig. 21.

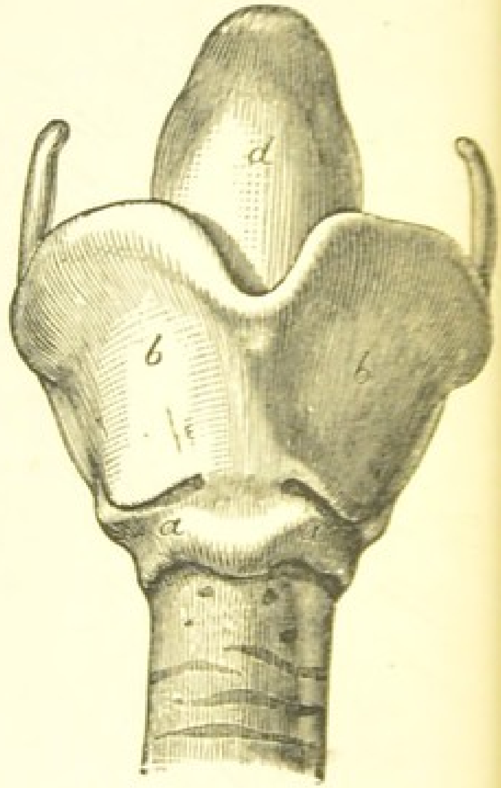


Fig. 22.

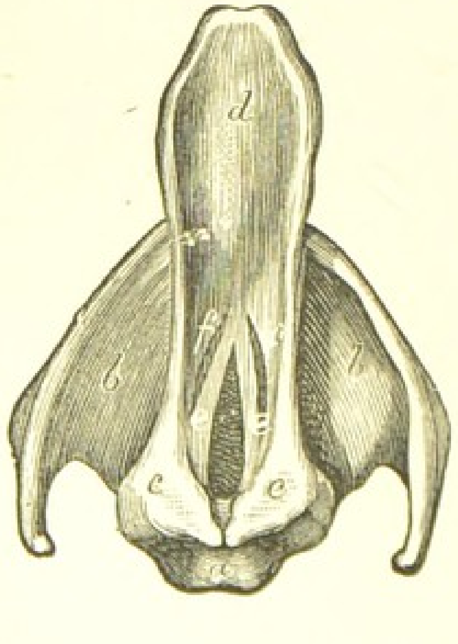
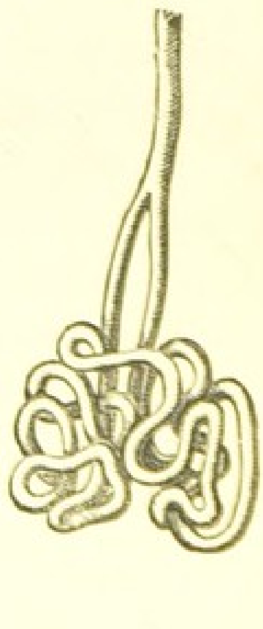


Fig. 23.



EXPLANATION OF PLATE VIII,

Showing portions of the structure of the Circulating System, the Respiratory Organs and Skin, referred to in paragraphs 43, 51, and 62.

Fig. 20. Magnified representation of the web of a frog's foot to show the capillaries. They are found between the arteries on the one side and the veins on the other. By the aid of a good microscope the blood-globules may be easily seen making their way in single file through these minute vessels in a living frog.

Fig. 21 is the human larynx seen from the front; *a* is the ring cartilage; *b*, *b*, the thyroid cartilage; *d*, the epiglottis.

Fig. 22. The larynx seen from above. *b*, *b*, the inside of the thyroid cartilage; *c*, *c*, pyramidal levers; *d*, the epiglottis; *e e* and *f f* are the boundaries of the vocal cords or *glottis*. It is while the air is passing through the latter that the voice is produced, and all the modulations of voice through the vibration of these cords. The epiglottis is seen in this diagram. Its function is to protect the glottis, and it is by this organ moving down upon the glottis that food and other substances are prevented from passing into the windpipe.

Fig. 23 exhibits a sweat gland. It passes through the skin and empties itself on the surface of the epidermis. The network formed by the tubes of the gland are seen below and the tube is often spiral.

sound dull, as is the case with the liver or other solid parts of the body.

51. One of the results of expiration is the passing of the air through a special apparatus, called the *larynx*. This organ is composed of five pieces of cartilage, and is so arranged that the air passing through it causes two membranes stretched across it, which are called *vocal cords*, to vibrate. The aperture between these cords is called the *glottis*. The vibration of these membranes, modified by the tongue, lips, and nose, produces what is called voice. All the modifications of sound which give rise to voice and speech result from the air in the lungs as it passes out of the air passages impinging on these vocal cords. These living vocal cords act in the same way as the reeds of a clarionet, and all the modifications of sound which are known as voice, and which result in all the known expressions of the human voice, are thus produced. This is really one of the most wonderful parts of the human mechanism, as by its agency that great distinguishing feature of human existence, language, is produced. All the known sounds of the human voice, which cause the vast variety of languages of the human race, are owing to modifications of the sounds produced by the human larynx. It is not, however, the capacity of this organ to produce sounds, and to give them expression by modifications of the organs of the mouth and face, that constitutes the real difference between lower animals and man, but it is that man possesses in his brain (the seat of the mind) a larger power of controlling the movements of these organs than any of the lower animals have.

52. One of the great results of taking the oxygen

of the air into the blood, is the production of animal heat. It we take a Fahrenheit's thermometer and place it on any covered part of the human body, it will be seen to rise to a temperature of 98°. Water freezes at 32°, and boils at 212°. The heat of the air in Great Britain varies from below 32° in the winter, up to 80° or 90° in the summer. Whether exposed to one temperature or another, the heat of the body is always 98°, thus showing that its heat depends on internal sources. This heat is produced by the contact of the oxygen of the air with the carbon and hydrogen contained in the tissues and the blood. The food containing carbon and hydrogen is brought in contact with the oxygen of the air, and uniting with the carbon and hydrogen in the blood and the tissues is converted into carbonic acid and water. When carbon and hydrogen are burned in an ordinary gas lamp, in contact with the oxygen of the atmosphere, heat is produced. Just in the same manner when the oxygen in the body comes in contact with the carbon and hydrogen taken into the system by the food, heat is given out. But not only do the foods containing carbon and hydrogen give heat, and also at the same time *moving* and *nerve* force, but the nitrogenous matters (albumens) in the blood also do this, and can do it alone without any non-nitrogenous foods (17, 18, 19). These last, however, (fat, starch, and sugar) cannot act alone, but seem to require nitrogenous matters to start them, combining with the oxygen, just as a percussion cap starts the gunpowder in a gun. It is this heat which maintains the life of the body. The temperature of different animals varies; it is 112° in ducks and geese, and 80°

in the elephant. The heat of the human body remains at the same point during health. In fever and inflammation this heat is increased, and in such diseases as cholera it is very much decreased.

53. In order that the function of respiration should be carried on properly, it is of the first importance that the air which is taken into the lungs, should be *pure*. If there is a deficiency of oxygen in the air breathed by a human being, the changes necessary to the production of animal heat do not take place, and a corruption of the blood ensues. The air breathed by human beings is constantly liable to a deficiency of oxygen, by its corruption during various artificial processes of combustion. Thus, in a room lighted with gas, the gas will consume so large a quantity of oxygen as to diminish the supply for persons remaining in the room. One of the great drawbacks in our present civilisation is the practice of introducing gas into our sitting-rooms, bed-rooms, workshops, and factories, without making sufficient arrangements for the supply of the oxygen gas consumed by the lights. One gas-light of an ordinary kind consumes during burning as much oxygen as five human beings, and where no provision is made for a supply of fresh oxygen, the air is most injurious to health. In the same way a large number of human beings, congregated in a small room, will consume the oxygen and render the air unfit for maintaining healthy life.

54. Not only do the combustion of gas and candles, and the respiration of human beings, consume the oxygen of the air, but they make it impure by giving off carbonic acid gas. This gas is given off

from burning lamps, and candles, and breathing human beings. It is a most destructive gas. If a jar of carbonic acid is collected from the burning of lights or fires, or the breathing of animals, no light can be burned in it, no animal can live in it. When sent forth from the lungs of animals it is instantly got rid of in the operation, and a natural ventilation is established; but when it is confined in rooms, it is breathed again and again, and the most disastrous effects follow. When carbonic acid is retained in the blood, it prevents those changes taking place which are necessary to health; and a variety of diseases are the result. One of the most common and obvious results of breathing an atmosphere charged with carbonic acid, is the production of the diseases known as scrofula and consumption. In those districts of London and other large towns of Great Britain and Ireland, where is the greatest overcrowding, there scrofulous diseases and consumption are most prevalent. Not only are these diseases prevalent in such places, but persons exposed to the action of carbonic acid are much more liable to fevers and other diseases, than those who obtain a due supply of fresh air. Of so much importance is fresh air to the health of man, that the Government insists that in every family there should be five hundred cubic feet of air for each individual. Away from large towns and cities, and especially at the sea-side, the more active form of oxygen called ozone is present (4). This accounts for the invigorating influence of country air and sea-side air, as compared with the atmosphere of towns and cities. Ozone is given off from growing plants both in the land and in the water.

55. As it is necessary that the air supplied to human beings should not be contaminated with carbonic acid, and contain a sufficient quantity of oxygen, so it is of the utmost importance that it should be free from *all* contamination. The air we breathe may contain *mechanical* particles which, coming in contact with the delicate membranes of the air passages of the lungs, may produce disease. Thus, in certain occupations, the air may be charged with minute particles of foreign matter which, getting into the lungs, may produce disease. The stone-cutter may inhale such particles of stone which, getting into the lungs, produce cough, and at last accumulate in so large quantities as to produce disease and death. The workers in iron in grinding inhale metallic particles which, sinking into the lungs, produce "grinder's asthma" and death. In cotton-cloth manufactories the particles of cloth and wool are taken into the air passages of the lungs and produce disease. In all households the particles of cotton and linen, and wool, getting into the air of rooms, may be taken into the lungs and cause disease. Constant exposure to the dust of factories, or even roads, may cause accumulations in the lungs which may be the sources of disease and death.

56. But the most dangerous contamination of the air is that which arises from the diffusion in it of vegetable and animal poisons. When plants and animals are dying or dead they give off small particles of matter which, entering the human lungs, pass into the blood and produce disease. These particles though apparently dead, possess the power of producing in living particles the same decomposing

condition in which they themselves are. It is thus that the particles rising into the air from drains and dead bodies, may produce in the living body the most fatal and destructive diseases. Many forms of fever are known to arise from this source alone. Amongst others may be mentioned drain fever, which carries off from fifteen to twenty thousand human persons every year in Great Britain, and which is certainly dependent on the putrescent matter of drains being taken into the human lungs and carried into the blood. The decaying matter of plants, such as their leaves and stems, in contact with water, gives forth an effluvium, known by the name of *malaria*, which produces the most violent and terrible fevers. The intermittent fever known by the name of *ague*, is thus produced, and the malarious fevers of sub-tropical and tropical climates are produced in the same manner. The great remedy for these diseases is *drainage*. All putrefying plants and animals should be got rid of at once from near the houses of human beings. It is the first duty of a man who possesses a house to see that all decomposing animal and vegetable matter is at once sent away, or placed at such a distance from the house that no human being can be injured by its presence. When deposits of this kind cannot be got rid of, they should be *disinfected*. There are many things commonly sold in shops for this purpose; amongst them we may mention chloride of lime, carbolic acid and the permanganate of soda and potash.

57. But besides these poisoning particles which are given off from all *dead* and *dying* animal and vegetable bodies, there are certain special poisons, which are

given off from *living* animal bodies which contaminate the air, and against which too active measures can hardly be taken. The human body is subject to certain diseases which, originating in the blood, produce particles in it which, given off from the body, are capable of producing the same disease. Such diseases are known by the name of small-pox, scarlet fever, measles, hooping cough, typhus and typhoid fevers, and cholera. When persons are attacked with these diseases, they are capable of giving off particles into the air which, when taken up by other bodies, will produce the same disease. By proper precautions all these diseases may be prevented from propagating themselves in other persons. With regard to small-pox, it is found that if persons are vaccinated, they are not capable of receiving the disease. Hence the duty of all parents to see that their children are early vaccinated, in order to prevent their taking this terrible disease. It is certainly a false notion to suppose that vaccine matter by itself can introduce any other disease than cow-pox into the system. There do not exist any ready means of preventing the other 'catching diseases,' but everybody knows that by proper precaution they may be prevented, and it is now one of the first duties of human beings, one to the other, to take care that by no careless act, the poison of these diseases should be conveyed from them to their neighbours. It is a common practice, much to be reprehended, to send children to school from families where small-pox, scarlet fever, measles, or hooping cough are prevailing, thus spreading the poison amongst those who have not been previously attacked.

58. The air being thus easily contaminated and rendered injurious to health and even life, it is of the first importance to secure *fresh* air, free from carbonic acid gas and all organic and poisonous impurities. In every house, sitting-room, bed-room, shop, workshop. school, or public building, provision should be made for the *getting rid of* the impure air, and the *letting in* of fresh air from without. This is done by what is called ventilation. There is a natural tendency of warm air to ascend, and advantage should be taken of this to have ventilators placed at the top of the room or building, so that the warm impure air may escape. In cold weather fires ventilate rooms, by a current of warm air ascending the chimney, and the cold, fresh air rushes into the room to supply its place. In warm weather rooms should never be shut up. When there is no other means of ventilation, the top sash of the window should be let down, so as to allow of the escape of impure air. All houses should be constructed with holes and valves, to let the impure air of the rooms out into the chimneys or into the open air.

59. Impurity of the air is constantly attended with the smell of gases which are disagreeable. This arises from the fact that when animal or vegetable matters are decomposing, the sulphur, phosphorus, and carbon contained in these matters, uniting with the hydrogen, produce a quantity of strong-smelling gases. These gases are not in themselves injurious in the small quantities in which they exist in the air, but they indicate the proximity of danger, and their warning should never be neglected. No air that smells is pure. These smells are given off from dustbins,

drains, closets, and cesspools, and wherever they exist immediate attention should be given to the cleansing of the places from whence they issue.

60. When diseases prevail in families which are infectious or catching, such as smallpox, scarlet fever, typhus and typhoid fever, and cholera, care should be taken to prevent the spread of the poison from the sick person to those who are well. No persons who are liable to take these diseases should remain in the room except those who are nursing. It should be recollected that the poisonous particles given off from the body may be so diluted as to prevent their acting on other persons, hence the sick-room should be supplied with as much fresh air as possible. It is found that the poisons of all the diseases mentioned are destroyed by the action of boiling water, hence all clothes and bed linen worn or used by those suffering from these diseases should be plunged into boiling water. These poisons are also destroyed by the disinfecting agents, chloride of lime, carbolic acid, and the permanganates. When boiling water cannot immediately be had, clothes may be submitted to these substances, and all vessels used in the bed-room cleansed out with them. In houses where death occurs, no one should be allowed to sleep in the room where the dead body is. It would be a good thing if in all cases of death the relatives could be persuaded to remove the dead body to a public mortuary, where it might wait, without danger to the living, any convenient period for interment This is especially the case of persons dying from contagious diseases.

CHAPTER VI.

ON THE STRUCTURE AND FUNCTIONS OF THE SKIN.

61. The warmth of the human body is constantly maintained at a temperature of 98° of Fahrenheit's thermometer. Whether a man exists in the arctic regions, or is an inhabitant of the tropics, this is the temperature of his body. We have seen that the source of this heat is not external, but that it is due to the consumption of combustible materials within the body itself (52). The carbon, hydrogen, and nitrogen of the food coming in contact with the oxygen of the air are the sources of this heat. The great agent by which the heat of the body is kept at a given temperature is the skin. In all animals the various organs are covered over with a skin. This organ, which is a thin membranous envelope in the lower animals, becomes more and more complicated as we rise in the scale of organisation. In the human body it is composed of two parts, the *cutis*, or lower skin, and a layer placed above this, the *epidermis*, or scarf skin. When we apply a blister to the skin, a portion of the epidermis rises, and forms a bladder or vesicle. This blister, as it is called, consists entirely of the epidermis, which is separated from the true skin below by the effusion of a quantity of serum or water. If we prick the blister the water exudes, and the epi-

dermis collapses. The epidermis covers the whole of the body, and can be traced into the mouth and nostrils, where it is continued in the form of the covering of the mucous membranes of the internal passages of the body, and is called *epithelium*. The epidermis consists of flattened cells; between it and the cutis lie the black-coloured cells, the presence of which produce the black and coloured races of mankind. The hair and the nails in human beings, and the beaks of birds, and the claws and horns of the lower animals, are all produced from the epidermis, and are called *epidermal appendages*.

62. The *cutis*, or lower skin, is supplied with capillary vessels, and to it is brought the blood of the whole body by the aid of these minute vessels. At the same time, the true skin possesses a number of small glands, which communicate with the capillaries on the one hand, and terminate in open *pores* through the epidermis, on the other. Between the pores and glands are minute ducts or tubes, which convey from the glands to the pores a fluid, which is called *perspiration*. It is calculated that there are not less than from two to three millions of these minute tubes upon the surface of a human body. The perspiration contains saline matters, carbonic acid, and other products, which are got rid of by the agency of the skin. The great function of these sweat ducts, however, is not to act as excretory organs, but to regulate the heat of the body. It is a well-known fact that when water is converted into vapour or steam, it changes or renders latent the heat which is employed in converting it into vapour. It is by means of this action that the skin becomes the agent

of regulating the temperature of the body. No sooner is the heat in the interior of the body raised by the oxidation of the food in the blood and tissues, than a certain portion of it is made latent by the conversion of the water into vapour in the perspiriferous canals. This process is constantly going on, and the vapour of the water passes off from the skin in the form of *insensible* perspiration. When large quantities of perspirable matter are thrown off, as during strong exercise, or in hot weather, the secretion from the skin condenses, and forms what is called *sensible* perspiration.

63. Besides the sweat-glands and tubes, the skin is the seat of minute sacs or depressions, which secrete a kind of fatty matter. These are called *sebaceous* follicles. The use of these follicles is to secrete an unctuous matter by which the epidermis is rendered soft, and to assist the decomposing action of the moisture of the skin on the cells of which the epidermis is composed. The practice of anointing in Oriental countries seems to have had its origin in imitating the function of these glands. In many of the lower animals these glands have a large development, as in some water-animals and most water-birds. In the human skin these follicles frequently get blocked up, and a little inflammation is the consequence, and what is called a pimple is produced. They are very numerous on the face and on the sides of the nose, and when not acting freely—that is, discharging their oily contents freely—their seat may be detected by a little black spot. If the skin be nipped round this spot a small thread of sebaceous matter will be squeezed out resembling a

worm; and by the ignorant these casts are regarded as worms. Occasionally, however, these follicles become the dwelling-place of a minute mite, called the *Demodex folliculorum.* This little creature has eight imperfect legs, is about the tenth of an inch in length, and belongs to the family of Acaridæ or Mites.

64. The practical result of our knowledge of the structure of the skin, is the necessity of keeping it clean. The perspiriferous ducts and the sebaceous follicles may both be so blocked up or covered over with dirt, as to prevent them from carrying on their functions. When this is the case, either the skin itself becomes diseased, and a variety of eruptions take place on its surface, or the blood is not properly relieved of its used-up products, and internal disease takes place. There is a close relation between the functions of the skin, the lungs, and the kidneys. They all of them carry off water from the blood, and when the function of one of the three in this respect is interfered with, the other is called upon to perform its functions. When the function of perspiration is interfered with, the lungs and kidneys are called upon to perform heavier duty, and this may lead to disease. In order then that the skin may perform its duties properly, it must, in the first place, be subjected to the action of water, and undergo the process of washing and bathing; and in the second place, it must be protected from the heat of tropical climates and of our summer, and the cold of arctic climates, and our winter by clothing.

65. The practice of washing the skin from head to foot every day, either by taking a plunge bath, a shower bath, or by a sponge or cloth dipped in cold

water, is much to be commended. Soft water is better adapted to this purpose than hard (26). In the summer in this climate, not only is the practice of bathing cleanly, but the application of the cold water to the skin produces a reaction, attended with warmth, which is very beneficial to health. In washing the skin it is desirable to add soap to the water at least once a day. Soap cleanses by dissolving the oily matter thrown out on the skin from the sebaceous follicles (64). It is this oily matter which attracts fine particles of dirt or dust in the atmosphere, and forms on the outside of the skin a layer of dirt. The best soap for use in washing the skin is curd or palm oil soap. Many soaps contain too much alkali.

66. In order that the skin may be kept in health, and its functions duly performed in relation to the heat of the body, it must be properly clothed. Man is the only animal that wears clothes, and they are necessary for his health and civilisation. It is essential to health that the body be maintained at a temperature of 98°. In hot countries, where man is unclothed, this is effected with comparatively small quantities of heat-giving food; but in cold countries, if man wears but a small quantity of clothing, heat can only be maintained by taking large quantities of food, and consuming this by constant exercise. Hence man, when but little clothed in temperate and cold climates, is a savage, who seeks in hunting to obtain large quantities of food, and by constant bodily activity to burn it in contact with the oxygen of the air. As man becomes civilised, and settles down in towns and villages, he finds it necessary to cover his

body, in order to prevent the radiation of heat from it. One of the great objects of clothing is to prevent the passing off from the skin of the heat of the body. In this way clothes act as economizers of food. According as the human frame is exposed to the cold of temperate and arctic regions, is the tendency to consume heat-giving food. Thus we have seen (20) that fat is one of the most efficient forms of food in keeping up the heat of the body. As we pass from tropical to arctic regions, we find man consuming larger quantities of fat in his food. The Russian adds oil to his meat pie to supply the means of maintaining his animal heat. The Greenlander and the Esquimaux eat the blubber of fish and other animals to keep up sufficient heat to resist the cold of their arctic climate. Even in Europe a change of diet is observable, according as the weather is hot or cold, and fatty foods are consumed with more avidity in winter than in summer. This is seen in animals. In temperate climates, all the mammalia get fat in the summer months, when little heat-giving food is required, whilst towards the end of winter they become lean, as the result of their fat having been consumed in maintaining their animal heat. Hybernating animals enter on their winter's sleep plump and fat, and wake up in the spring lean and emaciated, from the loss of fat used in maintaining their heat. Although there is this tendency to the accumulation of fat in the summer, and the loss of it in winter, even among sheep, dogs, and the like, a natural provision is made for their protection against cold. All animals clothed with hair in temperate climates have an increased quantity during the winter months, which is shed in the summer, and the animals of arctic climates are covered naturally with large quantities of hair.

67. The disastrous effect of cold on the system is seen in what occurs in the populations of our large towns, at the setting in of the cold season of the year. As long as the temperature remains some degrees above the freezing point, but little increase of death above the average mortality of the summer takes place, but directly the temperature gets below 32° (that of freezing water), old people and infants die off with diseases of the lungs, and the strongest suffer, more or less. This arises from the lowering of the temperature of the skin, by the action of the cold. The consequence is that the circulation of the blood is diminished in the capillaries of the skin, and the blood is sent to the internal organs, where, the vessels getting too full, congestions and inflammations occur. The organs which suffer most from this congestion are the lungs, but the heart, the brain, the liver, and kidneys may all become deranged, under the influence of cold. Short of serious disease, many inconveniences arise from exposure to cold; thus chilblains occur on the toes and fingers, and a variety of affections of the skin, such as inflamed patches, blotches, and even ulcers, which are very painful to bear.

68. One great object of clothing is to maintain such a temperature of the skin as shall prevent the evil results of which we have spoken. All people do not require to be protected from the cold alike. Infants are very liable to become injured by exposure, and unless they are kept from the external cold, fall under the influence of various diseases and die.

Persons leading a sedentary life, especially persons pursuing inactive occupations in the open air, require to be more warmly clothed than those who are taking active exercise. Everybody knows that when a man is going to run a race, or do hard work, he pulls off his coat, and as a rule it may be stated, that persons who take active exercise, whether indoors or outdoors, need less clothing than those who pursue sedentary occupations. The materials used by man for clothing are derived from both plants and animals. The physical qualities possessed by the substances used for clothing determine very much their use and advantage. The most common materials of this kind derived from the vegetable kingdom, are the fibres of *linen* and the hairs of *cotton*. The fibres of the flax plant were amongst the earliest used by mankind for the purposes of clothing. The fibres are prepared and woven into fabrics, which are made into clothes. In the same way the hairs of the cotton are woven and made into clothing, under the names of cotton, muslin, and calico. Many other plants yield fibres, such as hemp and jute, which are occasionally used for making articles of dress.

69. The materials used for dress, which are derived from the animal kingdom, are more varied than those from plants. The hair and the skin of animals principally supply the materials. Man first clothed himself with the skins of animals ; and the Britons, at the time of the Roman conquest, knew nothing of the luxury of linen clothing. The most common form of clothing derived from animals is the wool, which is yielded by the sheep. The hairs of which wool is composed are submitted to various preparatory processes, and are

at last woven and made into cloth. The hairs of many other animals are used in the same way, and recently, especially in the British Islands, the hair of the alpaca-goat. The skins of animals are prepared and converted into leather, which, on account of its being waterproof, is an admirable material for clothing the feet. The skins of animals are also prepared with their hair, constituting what are are called furs, which are used very extensively as articles of dress throughout the world. Another animal product used extensively for dress, is silk, which consists of the delicate fibres of the cocoon of a small moth. There are many other things derived from the vegetable and animal kingdom which enter into the composition of dress, but these are used for purposes of ornament, or convenience, rather than for keeping off the cold.

70. The reason why clothes keep the body warm depends principally upon the power they possess of resisting the conduction of heat. Some bodies conduct heat very rapidly, such as metals, which on that account feel cold when they are touched. On the other hand, substances containing air, such as wood, are bad conductors, and when they are touched do not feel cold. As a rule, those substances which contain most air in their interstices are those which conduct heat least, and are best fitted for being used as the materials of clothing. The fibres and hairs of plants, and the hairs of animals, are all substances containing air, and consequently bad conductors of heat. It is on this account that they are used for clothing. When placed upon the body they prevent the radiation of heat from it, and thus keep it warm. In the same way these materials are

used for the covering of beds. Blankets and sheets are as necessary for keeping the body warm at night, as clothes are by day.

71. In providing dress, however, it is important to know that some of the materials mentioned possess less conducting power in relation to heat than others, and that some materials are warmer than others. As a rule, all clothing derived from animals conduct heat more slowly than that derived from plants. All woollen clothing, consisting of cloth and worsted, of which so large a portion of the dress of the inhabitants of temperate climates is formed, is warmer than the various kinds of linen and cotton fabrics. Man clothes himself with furs in the colder regions of the world; and the habit of wearing flannel shirts and woollen dresses amongst Europeans arises from these materials not allowing the rapid conduction of heat from the body. On the other hand, in tropical and subtropical climates, where there is no necessity for protecting the body from a cold external temperature, the more rapidly heat-conducting tissues of plants are preferred. In fact, when man is exposed to the excessive heat of tropical climates, the necessity is not so much for clothing to keep *in* the heat of the *body* as to protect him from the direct rays of the *sun*.

72. Although not of the same importance as the property of conducting heat, colour is of some consequence in relation to clothing. When exposed to the action of heat, dark and rough substances *absorb* its rays best and *reflect* them least, whilst white and bright substances reflect heat best, and absorb it least. Thus, if we are anxious to avoid the sun's rays from

being absorbed by our dress, we should put on white material. The tendency to do this is seen in the practice of wearing white and light-coloured clothes in the summer, and in hot climates. It is not, however, on this account better to put on black and dark clothes in winter, for black and dark substances, whilst they *absorb* heat best, also *radiate* or give it off quickest, so that it is really better to wear light-coloured clothes both in summer and winter. There is no doubt that white clothing retains the heat of the body better than dark clothing. The true reason why the civilised inhabitants of Europe and America dress in dark-coloured clothes both in summer and winter, is economy. It is a question of *soap* and *washing*, and not of the comfort or use of the dress.

73. When the materials of dress have been chosen so as to secure the proper regulation of the heat of the body, care should be taken in wearing the clothes made from them, that they do not interfere with health. Beginning with the head then, although nature has supplied an ample covering in the hair to protect it from changes of temperature, man has chosen to protect and adorn his head with some kind of head-dress. The material of this article of clothing is not important as long as it possesses two qualities, that is, lightness and freedom from pressure. The Roman soldier wore a helmet to protect his head from the blows of his assailants, and the armies of Europe wear head-pieces of various kinds, having this object. Unfortunately the civilian has imitated the soldier, and often wears a hat which is at once unsightly and oppressive. A hat or a cap, serving all the

purposes for which the head needs to be covered, ought not to weigh more than five or six ounces. This hat or cap should fit loosely, so as not to press upon the veins of the head and obstruct the circulation of the blood. It is said that baldness is one of the results of wearing heavy and tight-fitting hats. The general practice of females in Europe of wearing light head-dresses, which are tied on under the chin, is open to little or no objection. The tendency, however, to load the head with heavy combs, and other ornaments, and to pad the natural hair, is likely to be injurious in various ways.

74. The dressing the neck is of more importance than the head. The great blood-vessels, bringing the blood from the head, are situated there, and pressure upon them may cost persons their lives. Women seldom dress the neck in such a way as to interfere with health; but the practice by men of wearing neckties and collars, constantly exposes them to the danger of compressing the blood-vessels of the neck. These articles of dress are really of no use, and, if regarded as ornamental, care should be taken that they are put on loosely. This rule should be also followed with regard to dress worn over the body. In this respect men are less likely to err than women. For many centuries, now in Europe, the attire of women has involved the wearing of what is called a corsette or stay. There is no article of dress that the folly of mankind has invented and perpetuated that has so little to be said in its favour as this, and yet its use is, perhaps, as extensive now as at any previous period. This garment, by its pressure on the external muscles of respiration, reduces their power; by contracting the

chest, it prevents the proper expansion of the ribs during the passage of the air into the lungs, and gives a stiffness to the movements of the upper part of the trunk, which prevents a proper action of the whole body. The effect of this article of dress is to distort the form, and to render it, as far as possible, the opposite of that most perfect representation of human beauty, the ancient statue of Venus.

75. In the dressing of the body, care should be taken that every part is properly covered. Amongst women the practice of exposing the neck and shoulders, especially when the weather is cold, is to be condemned. With regard to infants, the custom of putting them into short clothes, so as to allow them to walk with more freedom, and not clothing them beneath is a fruitful source of disease and death. The wearing of crinoline to distend the dresses of women leads to overloading the lower parts of the dress, and produces a strain upon the muscles of the back to support it. Not only is this practice dangerous to health, but the undue extension of the dress frequently brings it in contact with fire, and burns and death ensue. Upwards of three thousand persons annually lose their lives by burning in England and Wales. Half of these are women and children, who are burned to death by the inflammable nature of the linen and cotton clothes they wear. Both linen and cotton may be made uninflammable by being dipped in solutions of alum, tungstate of soda, sulphate of ammonia, and other preparations. If, after washing, all linen and cotton clothes were immersed in solutions of these salts, it would not only diminish the number burned to death,

but would prevent the much greater number of accidents from burning, in which women and children suffer agonies for weeks, but eventually recover.

76. The clothing of the extremities is of equal importance with that of other parts of the body. The practice of wearing short sleeves is open to objection where persons are pursuing sedentary occupations. The legs in children and grown persons should be clothed with stockings, and care should be taken to fasten them without pressing upon the veins which carry the blood from the feet and legs to the heart. Swellings of the feet, chilblains, and varicose veins are the results of fastenings tightly bound round the legs. The clothing of the foot ought to be attended to. Although children may be accustomed to grow up without shoes or stockings, there can be no doubt of their advantage, and the poorest of people, directly their means will permit, have recourse to them. The great object of the shoe is to protect the sole of the foot. At first men wore sandals, and eventually, instead of straps, the upper leathers of the boot and shoe were adopted. In wearing boots and shoes, it is the upper leathers which are the source of pain and danger. Boots and shoes should be made to fit the foot, and be neither so large as to cause slouching, or so small as anywhere to pinch the skin. Where the foot is too loose in the shoe chafing and ulcers may occur, and where it is too tight corns will grow, and in both cases the movements of the body are interfered with. The practice of attaching a heel-piece to the boot is very objectionable, as it elevates the heel, and gives the body a tendency to stoop, and taxes the toes by throwing more of the weight of the body

on them than is natural. The gait of a person with a high heel-piece is more like that of the gorilla or ourang-outang than that of the human being. These animals walk on their toes, and never bring their heels to the ground.

CHAPTER VII.

ON THE MOVEMENTS OF THE HUMAN BODY.

77. The ultimate destination of the food, after it has been converted into blood and carried into the capillaries, is to nourish the various tissues of the body. Each organ of the body is composed of certain tissues or textures, which have different names, and assume different appearances. The solid basis on which all the soft organs of the body rest is the skeleton. In the human body the skeleton is composed of a number of separate bones, each of which has a distinct name. In the animal kingdom there are two distinct forms of skeleton; the one which is found chiefly in the lower animals is outside, and covers the soft parts, and is called an exo-skeleton. Examples of this kind of skeleton are seen in crabs, lobsters, insects, and the shells of mollusca, as oysters, mussels, and whelks. The shells of these animals are mostly composed of carbonate of lime. Fishes possess an internal skeleton, and all the classes of animals above them, as reptiles, birds, and mammals, possess internal or endo-skeletons. These skeletons are all characterised by a series of central bones, which are called *vertebræ*. Hence, all the higher animals are called *vertebrata*, whilst the lower ones, which do not possess these bones, are called *invertebrata*. The bones of the higher animals are either *cartilaginous* or *osseous*.

The former kinds of bones are seen in such fishes as the shark and sturgeon, but most of the higher animals possess osseous skeletons. Amongst the highest animals, some portions of the skeleton remain cartilaginous, as is seen in the ends of the ribs, the covering of the ends of the bones in joints, and other parts of the human skeleton. When a very thin slice of the human bone is examined under the microscope, it is found to consist of fibrous, hard material, in which are a series of radiating bodies—black spots with lines running in all directions—looking like minute insects. These are really little cavities, and are called "*bone lacunæ;*" they are the active agents in the growth of the bone, and maintain the bones in their integrity. These cavities radiate around certain centres or tubes, which are called the Haversian canals, and which serve as passages for the minute blood-vessels and capillaries which nourish and cause the bone to live. The cartilages present much simpler cells than those of bone, and between them are deposited much larger quantities of *inter-cellular* matter than in bone. The cartilages also possess fewer blood-vessels than the bones. The teeth resemble bone in their ultimate structure. On the outside of all teeth is the *enamel*, which contains very little animal matter, and a great deal of mineral matter. The outsides of the fangs of the teeth are covered with bony matter, whilst the mass of the tooth is made of a substance called *dentine*, which stands between the bony matter and enamel in the quality of hardness, and is full of very little tubes, which meet in the middle of the *pulp*. It is this substance which is so largely developed in the tusks of the elephant, and produces ivory.

PLATE IX.

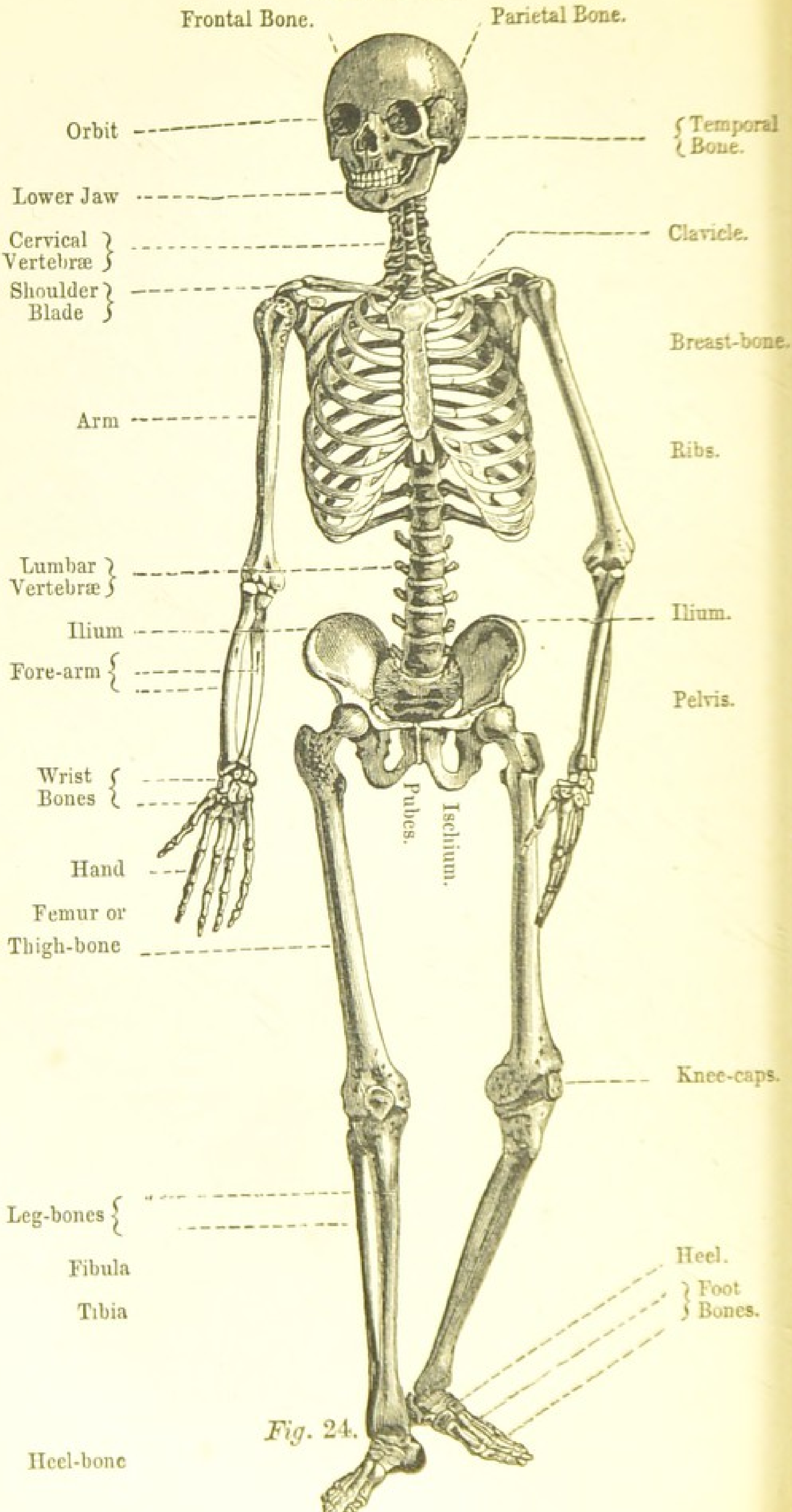


Fig. 24.

EXPLANATION OF PLATE IX,

Exhibiting the General Structure of the Human Skeleton, paragraph 78.

FIG. 24 exhibits the human skeleton. This constitutes the framework of the whole body. It will be observed that it is so constructed as to protect the more important organs of the body and to subserve the purposes of locomotion. The skull protects the brain, and the orbits in part protect the eyes, whilst the tongue, the nose and the ear, are provided with accommodation in the same part of the skeleton. The thorax or chest, with the backbone behind, the breastbone in front, and the ribs all round, protect the lungs and heart and the great blood-vessels. The backbone protects the spinal cord, and the pelvis other important organs.

A comparison of the head with that of other animals shows its large size and its adaptability from being supported on the spinal column to an upright position. The human skeleton has two hands and two feet, and is not four-handed, as in the highest monkeys.

The large size of the heel-bone enables man to assume and progress in the upright position. These and other points may be easily apprehended by a study of the human skeleton, of which the plate is an illustration.

78. The human skeleton is divided into three principal parts—the head, the trunk, and the extremities. The head comprises the bones of the *skull* and *face*. The skull is composed of several bones united together by means of toothed sutures, forming a cavity in which is contained the brain. In the bones of the face are the sockets for the eyes, and the passages for the nostrils, and the lower jaw is attached to it by joints, so as to allow of the opening and shutting of the mouth. At the bottom of the skull is a great hole called the *foramen magnum*, through which the brain is continued under the name of *spinal cord*, and which runs down the whole back through holes in the verte-bræ. The base of the skull also presents smaller holes, through which blood-vessels run to and from the brain, and nerves pass from the brain. The skull rests upon the back-bone, and the two upper verte-bræ are modified to enable the head to move freely without any interference with the functions of the nervous cord which passes through it. The trunk consists of the backbone and an upper and lower cavity. The upper cavity, called the *thorax* or chest, is bounded by the backbone behind, the breastbone in front, and the ribs on each side. The principal organs contained in the chest are the lungs and heart. The lower cavity of the trunk is terminated below by the bones of the *pelvis*. The bones of the extremities are those of the arms and legs. The long bone of arm is attached to the back of the chest by the *blade-bone*, which is also connected with the trunk by means of the *collar-bone* in front. The pelvis rests upon the two *thighbones*, which are connected at the knee-joint with the bones of the leg. The bones of the hands

and the feet are very characteristic of the structure of man. The animals nearest man—the *Quadrumana*, or monkeys—have practically four hands; but man is distinguished by having two hands and two feet. The arrangement by which man rests on his foot frees his hands for all the delicate purposes of touch and manipulation which makes him the most skilful of all animals. The distinguishing feature of the foot of man is the large *heelbone*, which enables him to bring the whole weight of his body directly over his two feet in an erect position. The heelbone (*calcaneum*) is very small in the highest monkeys. Their hind legs are, in fact, terminated by grasping organs, like hands, and they cannot stand in an erect position.

79. The muscles are attached to the bones of the skeleton. It is by means of their action that the bones are moved, and that all the actions of the human body are secured. When the muscle of any animal is carefully examined, it is found to consist of bundles of delicate fibres, which are bound together by a covering of connective or cellular tissue. Each bundle contains several *fibres*. Each one of these fibres contains a number of smaller and exceedingly minute fibres, called *fibrillæ*. These are composed of a number of square bits, attached end to end; and as these ends lie in a line when the fibrils are not torn separately, they give a *striped* appearance to the fibres which compose the muscles attached to the bones. These striped muscles are called *voluntary*, because they are supplied with nerves, over which the mind or will has control. There is another set of muscles which are connected with the soft organs, such as the gullet, stomach, and bowels,

and which are not under the control of the will. These muscles are called *involuntary*, and are composed of fibres which have no stripes. Such muscular tissue is called *unstriped*, and is characteristic of the involuntary muscles. The heart alone, amongst involuntary muscular structures, possesses striped fibres. The stripes in this case are much less decided than in the case of the true voluntary muscles.

80. The muscles are the organs by which all the movements of the body are effected. They are attached to the bones by means of tendons, which are strongly fastened to the bones. The tendons of one end of a muscle are attached to one bone, whilst the tendons of the other end of a muscle are attached to another bone. The great distinguishing property of muscular tissue is, that it possesses the power of *contraction*. When a muscle contracts, it is shortened, and by this shortening, the bones to which it is attached are moved. Every bone in the body is thus moved by the agency of the muscles, and the points at which the bones meet and move on one another are called *joints*. Each joint is composed of two bones, the ends of which are covered with cartilage, and the whole is enclosed and covered with a tissue called a *synovial membrane*. This membrane secretes a lubricating fluid called *synovia*. The synovial membrane is covered with *ligaments*, which bind the bones together. These ligaments are composed of a strong fibrous tissue, of the same nature as that of the tendons which terminate the muscles.

81. The muscles act upon the bones, and produce movements in them in the same way that levers act in moving machinery. There are two kinds or

orders of lever. The first is, where a *weight* to be moved is at one end of a rod, and the *power* which moves it is at the other end, whilst the point in which the rod rests, which is called the lever, is in the middle. A familiar instance of such a lever is a pump-handle. The power by which it is moved is the hand at one end, the weight to be moved is the water at the other end, whilst the pump itself is the lever. A still simpler example of this order is seen in the common balance, where the support is in the middle, and the two weights act as "power" to each other. An illustration of this form of lever is to be seen in the human body in the movements of the head. In all these movements the back or the front part of the head is the weight to be moved, the backbone is the lever on which the head rests, and the muscles attached to the back or the front of the trunk are the powers by which the head is moved in all the tossing and bowing movements which are so indicative of human character. In the second order of the lever, the three parts are differently disposed. The point of support, or *fulcrum*, is not between the weight and power, but beyond them. In this, as in the first order, there are two varieties—one in which the power is further from the fulcrum, the other in which the weight is so. Whichever is the further from the fulcrum has the greatest advantage. The first variety of the second order of lever is very common in machinery; but we see it in its simplest form when a man uses a hand-spike to move a weight. He places it under the weight to be moved, so that its end rests on the ground on some solid point, and then, by pulling up at the other end, the weight is moved. If we

PLATE X.

Fig. 25.

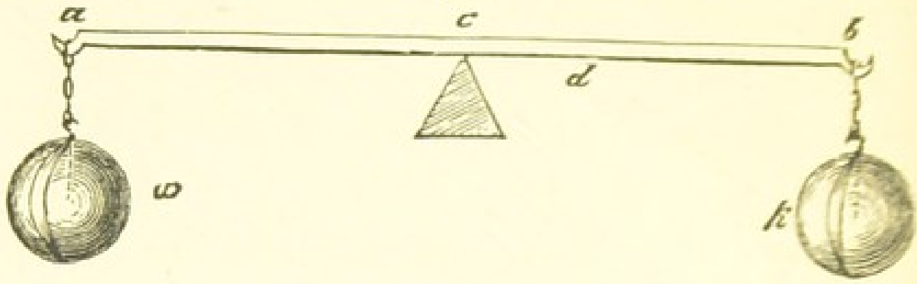


Fig. 26.

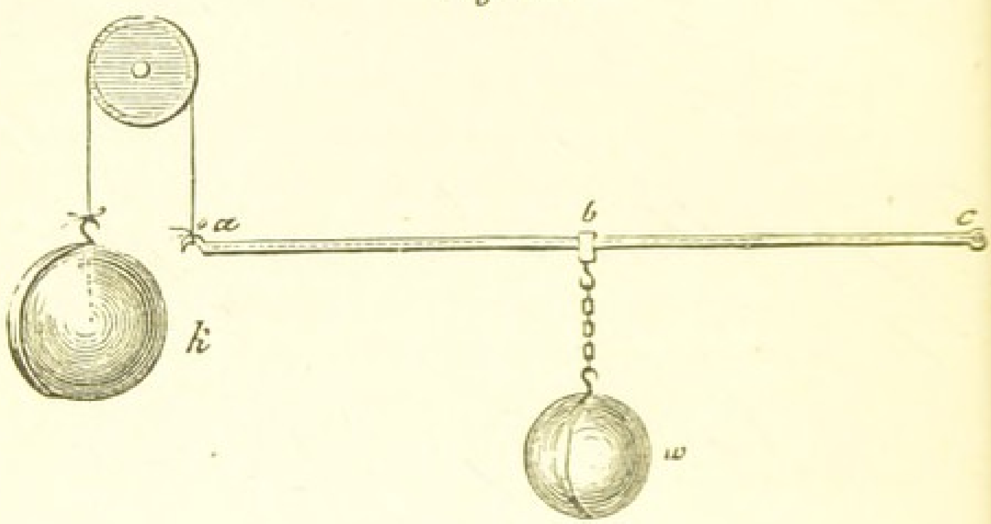


Fig. 27.

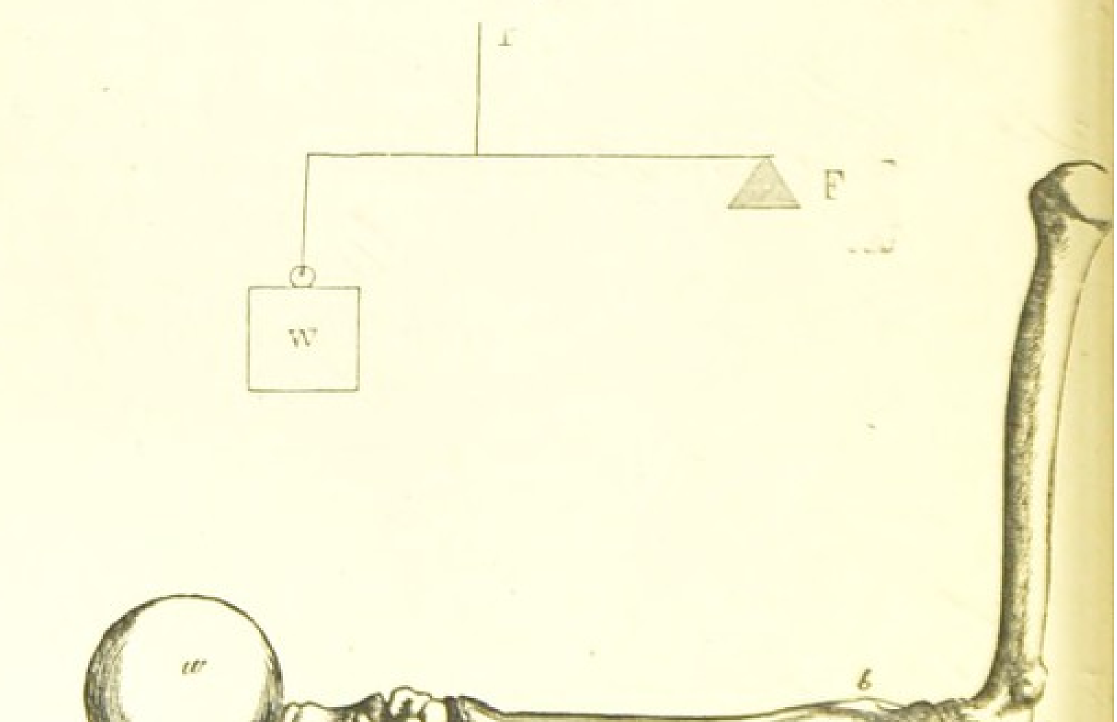


Fig. 28.

EXPLANATION OF PLATE X,

Showing the Action of the Muscles of the Body as Levers, and described in paragrayh 81.

FIG. 25 represents a common balance, and is an illustration of a lever of the first order. *c* is the pivot or fulcrum; *w* is the weight to be lifted; *k* is the power which is to lift the weight; *a* and *b* represent the ends of *d*, the rod. All the movements of the head are effected by such an arrangement of the muscles. The backbone represents the pivot or fulcrum, and the muscles represent the power which moves the head backward or forward, the head being the weight moved one way or the other.

FIG. 26 represents a lever of the second order, in which *w*, the weight to be moved, is in the middle, whilst the fulcrum is at the end, *c*, and the power that moves it at *k*. The foot represents such a lever, where the weight rests on the middle of the foot, and the toes rest on the fulcrum, and the power that moves is the muscle attached to the heel.

FIG. 27 represents a lever of the third order, in which the fulcrum is at one end, F, and the power that moves is in the middle, P, whilst the weight to be moved is at the other end. This form of lever is presented in all the long bones of the body.

FIG. 28 represents the upper and fore-arm of the human body. *a* is the joint which acts as the pivot, whilst *b* is the point where the muscle is attached, which acts as the power, and the hand, with the ball *w* in it, is the weight to be moved.

think of the human foot, we shall see that it is a lever of this kind. The toes are the end of a lever, the fulcrum of which is the ground; on the foot the whole of the body rests as a weight, and the power acts at the heel-bone, which is attached to the great *gastrocnemius* muscle forming the calf of the leg, which, by its contracting, becomes the power which moves the whole weight of the body. The other form of the second order of lever—that in which the weight is furthest from the fulcrum—is common in animals, since it gives quickness to movement. A familiar illustration of this is when a man lifts a ladder, by allowing one end to rest on the ground, whilst he grasps one of the lower ledges, and the rest of the ladder forms the weight which he lifts from the ground in rearing it upright. In this instance the power acts at a great disadvantage; but what is lost by the power is gained by the amount of movement which can be effected by the other end of the lever. In the human body this kind of lever is seen in action in the arm when the hand and forearm are raised by a muscle attached to the forearm near the elbow-joint. The forearm and hand are the weight moved, the elbow-joint is the fulcrum, and the *biceps* muscle, the great muscle of the upper arm, is the power which moves the hand and forearm. The extremities of animals are all moved on this principle, and afford abundant illustration of the mechanical principles in accordance with which the movements of the body are carried on.

82. In order that the various muscles of the body may be kept in health, they require to be moved. Hence *exercise* should be taken, which will put all the

muscles in motion. In the occupations of man, sometimes one set of muscles, and sometimes another, are engaged. When persons are employed in sedentary occupations, only a few muscles are employed, and such persons require general exercise, for the purpose of securing the action of those muscles which are otherwise not exercised. At the time that children are at school, care should be taken that during the hours they are out of school, regular exercise should be taken. Various games and amusements are recommended for this purpose. *Walking* a long distance in the open air is a good exercise, as it especially excites the muscles of the legs, and employs the respiratory muscles. The arms, however, are not sufficiently employed in this exercise. *Running* is also to be commended, on account of its exercising a larger number of muscles. Care should, however, be taken not to push running to excess, as it taxes the heart, and in excess may lay the foundations of disease of that organ. The various exercises of *dancing*, *jumping*, *skipping*, and the playing at games such as *foot-ball* and *cricket*, are all to be recommended as exercising a large number of muscles. *Rowing* in a boat is especially to be recommended, as it actively exercises regularly the muscles of the arms and chest and passively those of the legs and the lower parts of the body. *Swimming*, above all exercises, engages the muscles of the whole of the body; it can only be adopted in the open air in this country in the summer months, but in the winter it may be practised in warm water, which is supplied in many of the swimming baths of our large towns. *Riding* on horseback, though not attainable by all, is undoubtedly a most advantageous exercise, and to be commended where facilities are possessed for its indulgence. The great rule for the guidance of all persons, with regard to exercise, is to recollect that in order to secure the health of the body, every set of muscles should be exercised to a greater or less extent every day.

83. Where the ordinary forms of exercise cannot be procured, much is to be said in favour of a well-regulated system of exercises, which are often called *gymnastics*. The subject of the various movements of the muscles of the body have been a study by many writers, and they have recommended for children in schools, a distinct set of exercises, advancing from the simplest movements of the arms and legs, to complicated actions embracing more or less all parts of the body. Occasionally these movements are performed by the aid of music, so that time is kept, and the same pleasurable feeling is produced which accompanies dancing. The only instruments used in these movements are dumb-bells or sticks. In other systems of gymnastics, instruments of various kinds are used, and both in girls' and boys' schools, a portion of ground called the *gymnasium* is frequently set aside for the purpose of carrying on these exercises. These are sometimes accompanied by the *drill* exercise of soldiers, and superintended by a military man. It is very desirable that a gymnasium, with complicated apparatus, should be superintended by a person who can estimate the strength of the pupils, so as not to allow them to perform feats of strength beyond their powers, or to attempt exercises which are harmless enough to the instructed, but dangerous to those who

do not know how to perform them. In all gymnastic exercises, competition in feats of strength should be avoided. Boat-racing is only to be condemned on the ground that the strength is taxed beyond the powers of the system, and exhaustion, with sometimes permanent injury, has been known to follow severe competition.

84. The employment of the muscles in exercise not only benefits their especial structure, but it acts on the whole system. When the muscles are put in action, the capillary blood-vessels with which they are supplied become more rapidly charged with blood, and active changes take place, not only in the muscles, but in all other surrounding tissues. The heart is thus required to supply more blood, and accordingly beats more rapidly in order to supply the demand. A larger quantity of blood is sent through the lungs, and larger supplies of oxygen are taken in and carried to the various tissues of the body. The oxygen, by combining with the carbon of the blood and the tissues, engenders a larger quantity of heat, which produces an action on the skin, in order that the superfluous heat thus engendered may be got rid of (62). By this means the skin is exercised, as it were, and the sudoriparous and sebaceous glands are made to act and are kept in health. It is thus that by the exercise of the muscles, the lungs and skin are brought into action, and the lungs throw off large quantities of carbonic acid, and the skin large quantities of water, containing in solution matters which, if retained, would produce disease in the body. Not only are these organs benefited by the increased circulation of the blood, produced by exercise, but wherever the blood is

sent, changes of a healthful character occur. The brain and the rest of the nervous system are invigorated, the stomach has its powers of digestion improved, and the liver, pancreas, and other organs perform their functions with more vigour. By want of exercise, the constituents of the food which pass into the blood, are not oxidised, and products which produce disease are thus engendered. The introduction of fresh supplies of oxygen induced by exercise, oxidises these products and renders them injurious; all other things being the same, it may be laid down as a rule that those who take the most exercise in the open air, will live the longest; at the same time, it should be recollected that the action of the muscles has limits, as well as that of every other organ of the body. The muscles and the heart may be taxed too severely, and permanent derangements may be produced by overtaxing the human body. The ancient gymnasts among the Greeks are said to have become prematurely old, and the clowns and athletes of our own days suffer from the severe strain they put upon their muscular systems. It is even thought by some that boat-racing permanently injures those who engage in it; but these are examples of abuse. Persons should neither walk, run, leap, or play at any game, to the extent of producing permanent or painful exhaustion. All exercise is attended with pleasurable feelings, and when pain is produced by proper exercise, those who suffer should rather seek medical advice than persevere in exercise.

CHAPTER VIII.

ON THE BRAIN AND NERVES.

85. One of the distinguishing features between plants and animals is the possession by the latter of a nervous system. Not that all animals possess nerves, but it is through these organs that the great variety and multitude of the actions of higher animals are performed. The great feature of a nerve is that it acts under the influence of anything irritating it, which is called *a stimulus.* Some plants possess the power of moving, as is seen amongst the more minute forms, only detected by the aid of the microscope; whilst the moving of the leaves of the sensitive plant, the turning of sunflowers, and the closing of other flowers at night are familiar instances of higher plants having the power of motion. These movements, however, do not depend on the plant possessing either a nervous or a muscular system, but on their possessing a living matter which combines the two properties of *sensibility to a stimulus* and *motion*, properties which are found respectively in the nerves and muscles of the higher animals. Many of the lower animals possess no visible nervous system, and are influenced by external stimuli in the same way as plants.

86. Many of the minute plants which move in water are endowed with organs called *cilia.* They are always found on the surface of the motile

Plate XI.

Fig. 29.

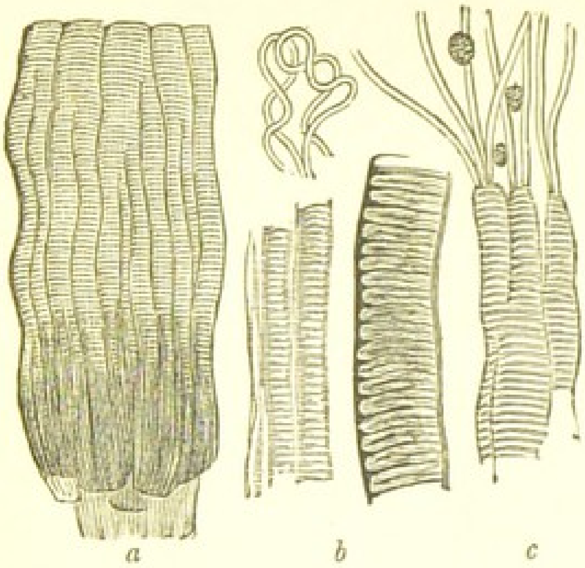


Fig. 30.

Fig. 31.

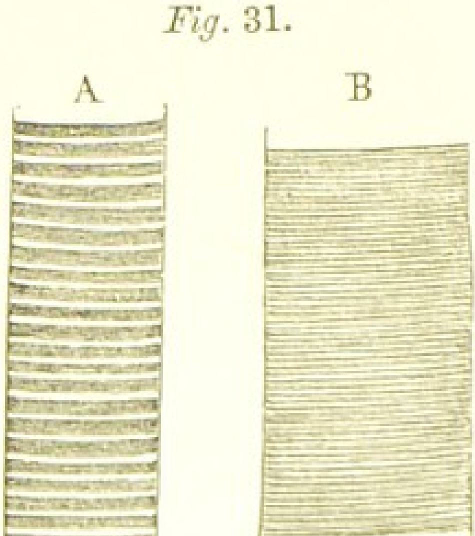


Fig. 32.

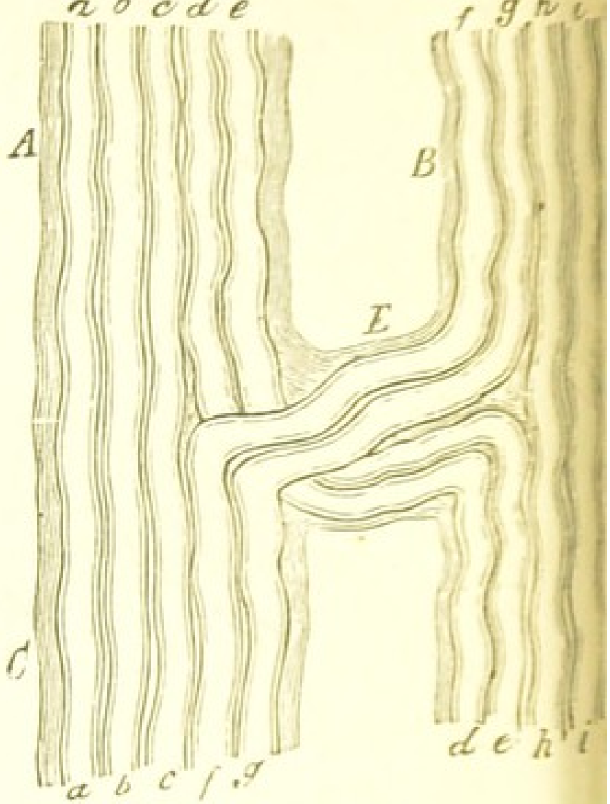
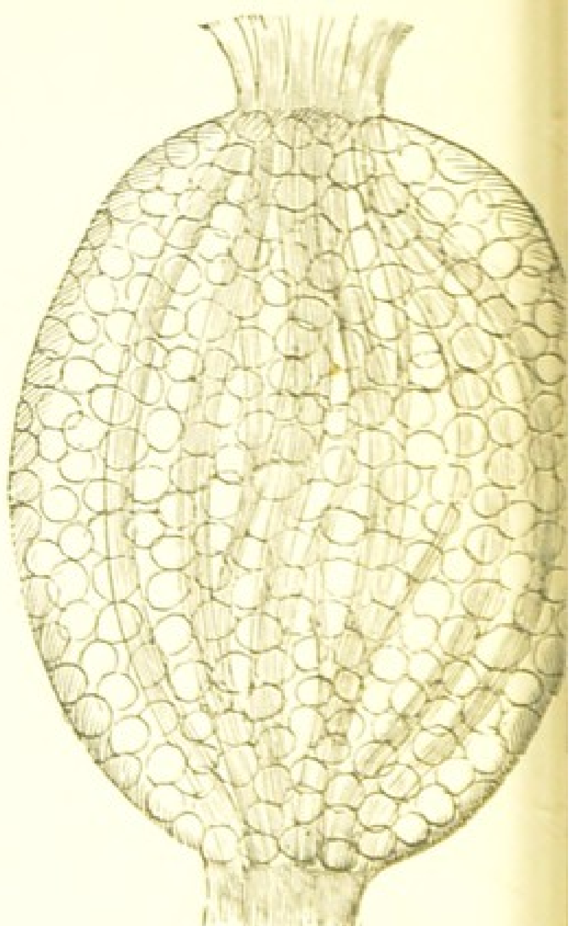


Fig. 33.



EXPLANATION OF PLATE XI,

Exhibiting the Minute Structure of Muscles and Nerves, which is described in paragraphs 79, 87 *and* 88.

Fig. 29 is a representation of the muscles as they appear under the microscope. *a* is a bundle of muscular fibres; *b* represents single fibres; and *c* represents these fibres separately, with fibrillæ. The fibrillæ are composed of a series of cells, which, laid one upon another and side by side, give the striped appearance to the voluntary muscular tissues.

Fig. 30 represents a muscular fibre contracting.

Fig. 31. A represents the muscular fibre in a state of quiescence; B is the same fibre in a state of contraction. B is broader, but shorter, than A. This shortening shows the nature of the force by which the muscles on contraction become the means of moving the bones to which they are attached.

Fig. 32 represents nerve-tubes. A, B, C, E are the sheaths of the tubes; *a, b, c, d, e, f, g, h, i, k,* represent separate nerve-tubes. At E is seen how they cross from one side to the other of a nerve, and explain how nervous energy passes from side to side of the nervous system.

Fig. 33 represents a ganglion. In the centre of ganglion will be seen the nerve-cells, whilst passing through the ganglion will be seen nerve-tubes which convey sensations and volitions through the ganglion.

plant, which usually consists of a single vesicle or cell. Sometimes there is only one of these little organs, or one at each end of the cell; at other times the whole cell is covered with them. They are brought into action by the agency of heat and light, and are constantly moving, and it is by the lashing of these minute hair-like bodies that the plant moves. Cilia are almost universally present in the animal kingdom. They are found on the surface of the minute one-celled animals called Infusorial animalcules and some worms, and they are present in the interior organs of all higher animals. They are especially seen in the respiratory organs, and may be conveniently examined on the gills of an oyster or mussel. They are found in the mucous membrane of the human nose and windpipe, in the hollow parts of the brain, and other parts of the body. In those parts their function is to act upon the mucus secreted by the membrane, and to sweep it, as it were, in the direction in which it ought to pass from the organs on which they are placed. In these cases four or five of these minute cilia are placed upon a single cell. In man they are not more than from the $\frac{1}{4000}$th to the $\frac{1}{2500}$th of an inch in length. Yet on these minute agents the life of the animal kingdom may be said to depend. Though influenced by external stimuli, their movements are quite independent of the nervous system, and they will continue to move for hours after they have been removed from the body.

87. The nervous matter is composed of two things, viz., minute *cells* and delicate *tubes*, which can only be seen by the aid of the microscope. The cells are of various shapes, generally containing a minute spot or

nucleus in the centre. The nerve-tubes are very fine and delicate cylinders, with a second cylinder in their interior, around which is contained a fluid peculiar to these organs. The nerve-cells or corpuscles are minute bodies with a kernel and long branching processes, which unite either with each other, or with nerve-tubes. The nerve-cells or corpuscles are found in the *ganglions*, or swellings of the nerves, whilst the tubes are found in the nerves themselves. A number of these delicate tubes are bound together by means of a membranous sheath composed of *connective* tissue. The same tissue binds the muscular bundles together, and is found all over the body binding and keeping the other organs together. When the matter of which the nerves are composed is examined, it is found to contain about ten per cent. of an albumen, ten per cent. of fatty and saline matters, and eighty per cent. of water.

88. The simplest form of a nervous system consists of a ganglion containing nerve-cells, and a nerve containing nerve-tubes. Such a simple structure is, however, seldom found even amongst the lowest animals which have nerves. What we find, as for instance in the starfish, is a series of ganglia, arranged in a circle round the mouth, and attached together by nervous cords, and giving off in various directions little nervous twigs. In worms, insects, crabs, and lobsters, we find a double row of nervous ganglia, forming two lines, which are connected together by nervous cords, and give off to the legs and other organs nervous twigs. In whelks, snails, oysters, and other shell-fish, the ganglia are situated in various

PLATE XIV.

Fig. 38.

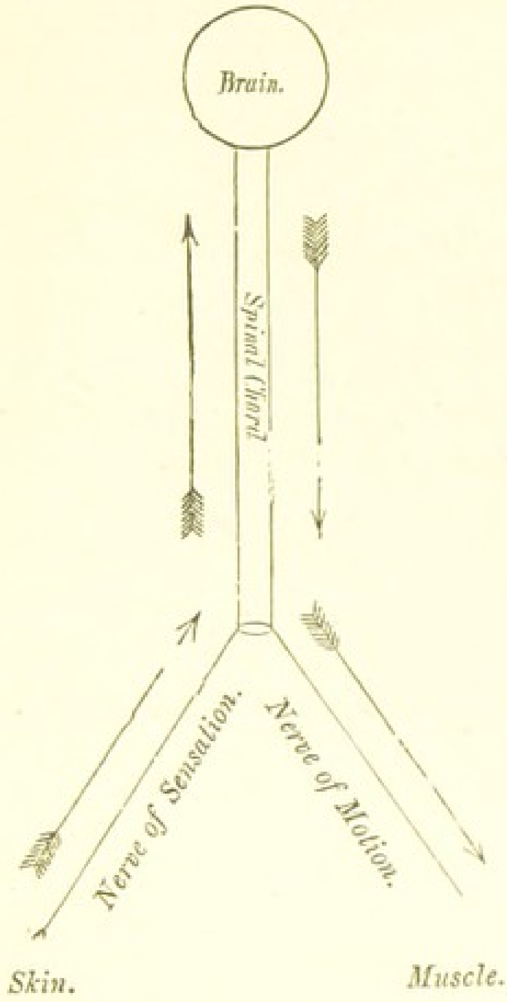


Fig. 39.

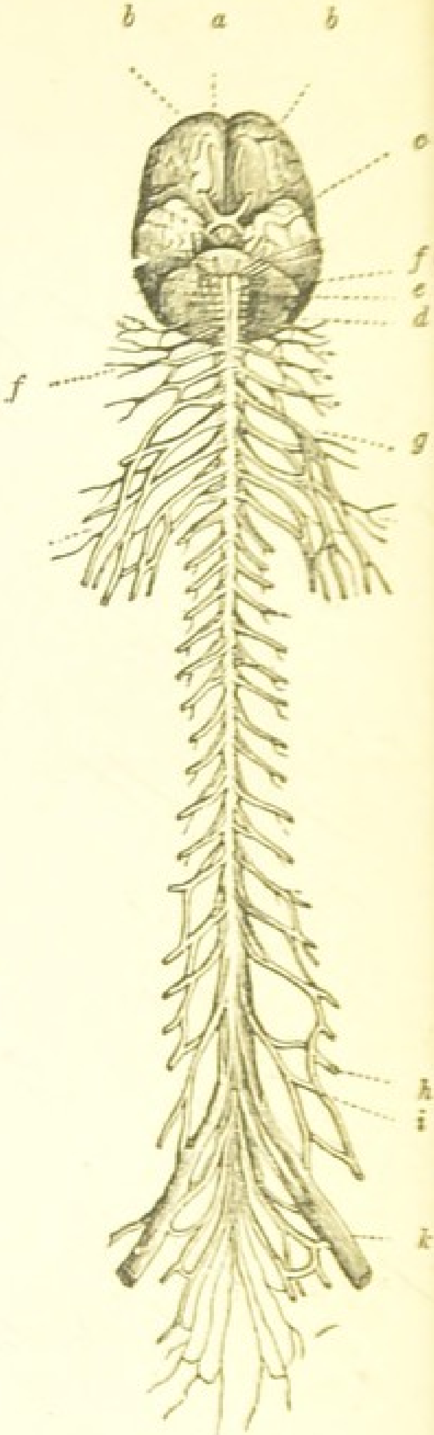
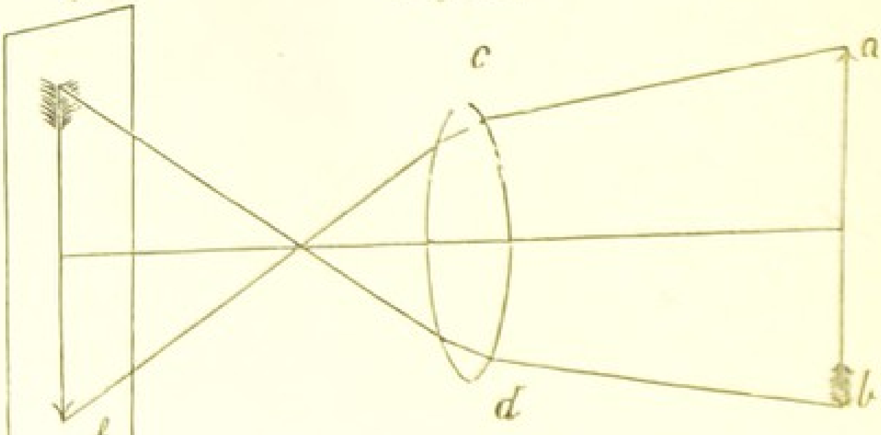


Fig. 40.



EXPLANATION OF PLATE XIV,

Illustrating the Functions and Structure of the Nervous System and the Organs of the Senses, referred to in paragraphs 89, 90, 91, 93 *and* 95.

Fig. 38 is a diagram representing the functions of the brain, spinal cord and nerves. The brain may be regarded as the terminus of a railway station. The nerves of sensation represent the up-lines, whilst nerves of volition or motion represent the down-lines. In all the ordinary nerves these two sets of nerves are combined together, but in some of the nerves proceeding from the brain the two are separated. Thus, the *third*, *fourth*, and *sixth* nerves proceeding from the brain are nerves of motion, whilst the *fifth* nerve is entirely a nerve of sensation.

Fig. 39 represents the brain and spinal cord seen from the front. *a* is the fore-brain, which is divided into three lobes; *b*, the front lobe; *c*, the middle lobe; *d*, the hind lobe. The hind-brain, consisting of *e*, the cerebellum, and *f*, the medulla oblongata, is also represented. From below the medulla oblongata the spinal cord gives off thirty-one pairs of nerves; these are seen in the diagram passing off from the spinal cord—*g*, nerves of the neck; *h*, nerves of the hips; *k*, the great sciatic nerve. Each of these nerves contain nerve-tubes for conveying up sensations, and nerve-tubes for conveying down volitions. The nerve-tubes of sensation and volition have different origins in the spinal cord, the nerves of sensation proceeding from the back of the spinal cord, and nerves of motion proceeding from the front. They start from the cord with separate roots, and unite before they proceed on their common course.

Fig. 40 is a diagram representing the way in which the rays of light passing through a lens causes an inverted image, and shows how images passing through the eye become inverted on the retina; *a b* is an object which, passing through the lens, *c d*, becomes inverted on the screen *e f*.

parts of the body, and are all connected together to form a common nervous system.

89. The function of a nervous system, however simply constructed, is to receive impressions from without, and to convey force from within. The ganglion is always the centre of these two actions. It may be compared to the terminus of a railway; and the nerves which bring impressions from without are like the up-lines of railway, whilst the nerves which convey impressions from within are like the down-lines. The nerves which go up to the ganglia are called by various names; they are called *sensory* or *sensitive*, as they receive the impressions which produce what we call *sensations*. They are also called *afferent*, and, since they run *to* a centre, are also called *centripetal*. On the other hand, the nerves which convey impressions *from* the ganglia always have the power of causing some kind of motion. They are hence called *motory* or *motor* nerves. In the higher animals they are under the control of the will, and are also called *volitionary*. As they come *from* a centre they are said to be *centrifugal*, and as they go outwards are called *efferent*.* The efferent and afferent nerve fibres are bound together in the same nerve, and cannot be distinguished by the eye.

* The use of these terms will be understood best by the following diagram:

GANGLION.

Nerves.	*Nerves.*
Motor.	Sensory.
Volitionary.	Sensitive.
Centrifugal.	Centripetal.
Efferent.	Afferent.

Nerves end differently according to the different uses they have. Those going to the muscles (motor) spread out in a very fine network all round the muscle-fibres, whilst those nerve-tubes which carry sensations end in little nobs in the skin, or in organs like the eye.

90. The result of impressions on a chain of ganglia like that in a worm is to produce motion in those muscles which move the body. Such a system is called *excito-motory;* and it is the means by which simple movements of the body are effected in all animals. When the digestive and respiratory functions in animals require special superintendence, nervous ganglia are added for this purpose; and in the higher shell-fish ganglia are observed accompanying the development of the digestive and respiratory organs. The movements accompanying the performance of the functions of these organs are all the result of the stimulus of the food and of the air or oxygenated water on the nerves. In man, and the vertebrate animals, the nerves which receive impressions from without, and those which go to muscles subject to the will or consciousness, spring from a great mass of nerve tubes and cells which lies in a bony case, and forms the *brain* and *spinal cord.*

91. When the organs of the senses begin to be developed in the lower animals, they are connected with special ganglionic masses, and the nerve which receives the external impression, runs to the ganglion. In these cases, motion is produced as the result of impressions on a special organ of sense. The organ of sense which is first developed in the lower animals is the eye; and we see, amongst the insects especially,

a ganglion supplied to the nerves of the eye. The movements of insects seem more especially determined by the impression of external objects on their eyes. Such movements, whether they result from impressions on nerves of sight, hearing, taste, smelling, or ordinary sensation (pinching, &c.) are called *sensori-motor*. In man and the higher animals such ganglia of great size are seen at the base of the brain, and are connected with the nerves of the nose, eye, and tongue, and also with nerve-fibres from the furthest parts of the body through the spinal cord. These great masses are called the "ganglia of the brain," also the corpora striata, optic-thalami, corpora quadrigemina, &c. The movements due to these ganglia in man, and to their representatives in lower animals, are quite independent of *will*. But these *sensori-motor* actions differ from *excito-motor* actions in that we *know* or feel the stimulus, though we cannot prevent the action. Such are blinking when a bright object is placed before the eye, sneezing when snuff is applied to the nose, starting when sound is applied to the ear, jumping when pinched, also the first act of swallowing is of this nature, as also is breathing in part; for these actions cannot go on when the sensation of the throat or lung is lost by the destruction of nervous connection with the great brain ganglia.

92. There is a last stage in the development of the nervous system of animals, which consists in the production of an organ which is not connected with any special group of nerves. This consists of two masses of nerve matter, called sometimes the "hemispheres," sometimes the brain-proper, or cerebrum but best distinguished from the other parts lying in the skull

or brain-case, as the fore-brain. It is peculiar to the back-boned animals, and is not even represented in insects, molluscs, &c. The fore-brain is altogether the most important mass of nervous matter. It receives impressions from all the other parts of the body; and the impressions it thus receives are more or less permanent, and are called *ideas.* It thus becomes the seat of consciousness, and above all of memory; and by its action the animal has the power of determining which of two lines of action it shall take; and this is called *will.* Hence the cerebrum is also the seat of volition or voluntary action. At the same time it acts on the muscles, sometimes independently of the consciousness; and such actions are called *ideo-motor*. Such actions as these are seen when persons are asleep, when they can be persuaded to act on any suggestion made to them by persons standing by. An illustration of such action is seen in the exhibitions of the so-called "electro-biologists," in which by means not fully understood persons are deprived of the natural influence of their consciousness, and they perform very absurd movements under the idea that they are drunk, or on fire, or in danger of falling, or other accidents.

93. Having thus described the general characters of the nervous system in the animal kingdom, we now proceed to describe that which exists in the human being more fully. In man we have a brain and spinal cord, or *cerebro-spinal* system, and a second system called *sympathetic*, which is particularly connected with the soft organs. The brain is divided into a fore-brain, a mid-brain, and a hind-brain. The fore-brain or "hemispheres" is split down the middle, and

Plate XIII.

Fig. 35.

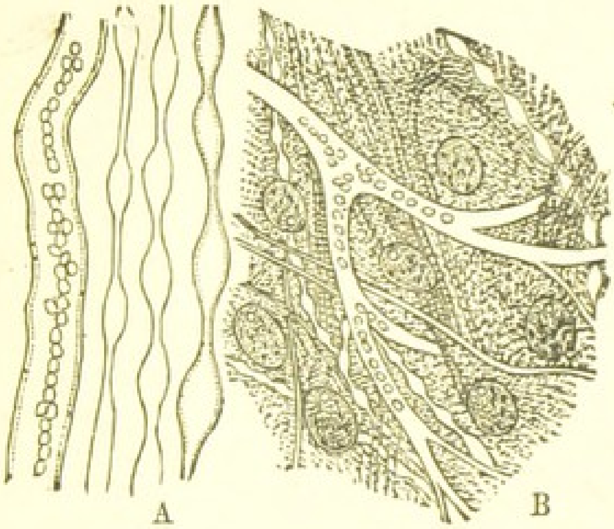


Fig. 36.

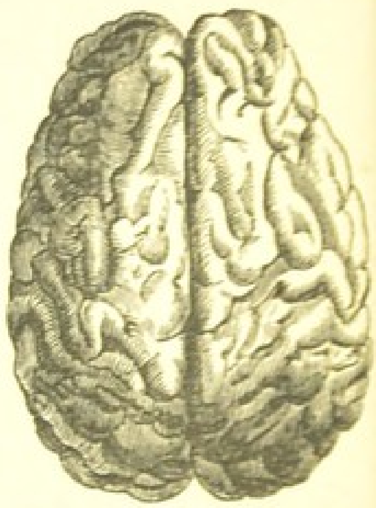
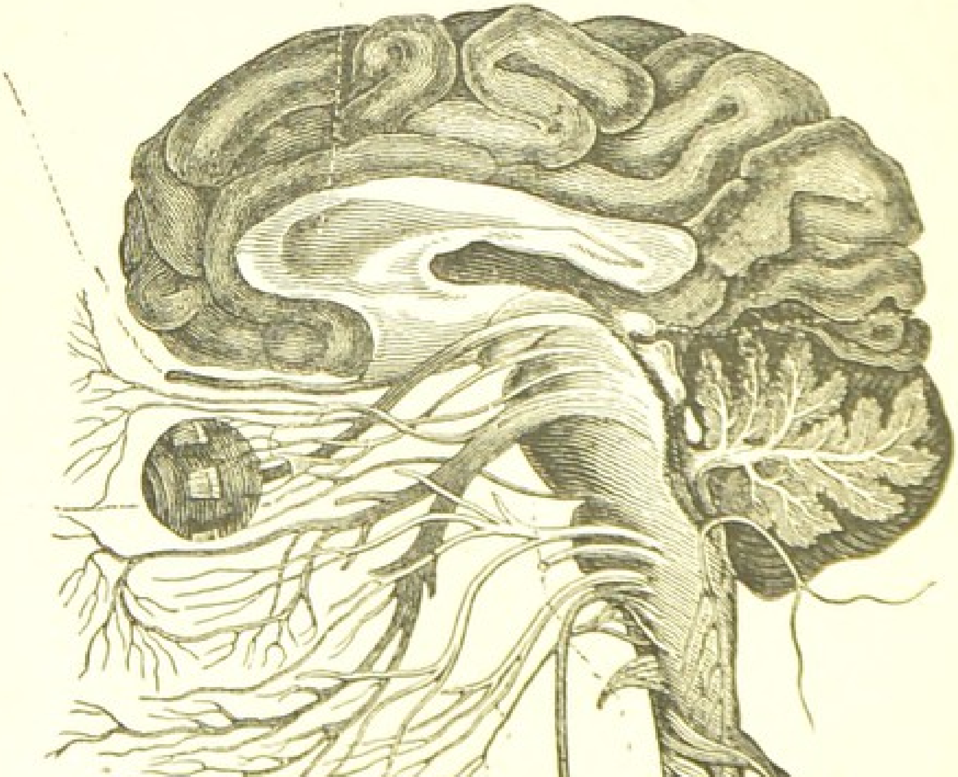


Fig. 37.



EXPLANATION OF PLATE XIII,

Illustrating the General Structure of the Brain and the Nerves of the Senses, referred to in paragraphs 93, 94 and 96.

Fig. 35 represents a portion of nerve-tissue under the microscope. A exhibits the nerve-tubes and the various forms they assume; B shows a portion of brain-tissue in which the tubes which convey sensations and volitions are mingling with those cells by which impressions are received and the mandates of the will or the controlling force of the nerves are communicated to the muscles.

Fig. 36 represents a view of the fore-brain from above. The division between the two hemispheres is seen, and the covering of the middle and hind-brain is obvious. Hence Professor Owen refers the family of man to a separate family called Avchencephala, on account of their fore-brain concealing all other parts of the brain.

Fig. 37 exhibits a section of the human brain, representing the fore-brain, mid-brain and hind-brain, with the nerves of the senses. The nerves of special sense are seen passing to the nose, the eye, the ear, and the tongue, also the great nerves given off from the medulla oblongata. The double origin of the spinal nerves is seen in the spinal cord.

is curiously wrinkled and folded; in man it is very large, and spreads backwards over both the mid- and hind-brain. At its base, or rather enveloped by it, is one of the large ganglia of the brain. The two sides of the fore-brain are, as we said, separated by a deep groove, running from front to back, but at the bottom of this is a mass of nervous matter, which unites the two sides together. This mass of nervous substance contains nerve-tubes, which run across each other from one side to the other, and explains the curious fact, that when one side of the brain is injured the functions of the opposite side of the nervous system, below the spot where the tubes cross, is affected. The outside of the lobes of the fore-brain present a series of elevations and depressions, which are called *convolutions.* When cut into, this great reflected mass presents externally a *greyish* colour, and internally is *white.* The grey matter consists principally of nerve-cells, and is supposed to be the source of that power which the brain and ganglionic masses exert on the nerves. The white matter is composed of nerve-tubes or fibres. The whole brain is covered over with three membranes, one a strong, fibrous membrane, called the *dura mater*, which lies next the bone, another, more delicate, the *pia mater*, through which pass the blood-vessels that nourish the brain, and a spongy intermediate membrane. It is these membranes which become inflamed in inflammation of the brain, and which become congested under the influence of alcoholic drinks. By habitual drunkenness these membranes become thickened and rendered opaque, and thus offer an obstruction to the circulation in the brain, leading to *apoplexy*, which is caused by blood being effused on the brain, and softening of its substance. It is the action of alcohol on the circulation of the brain that leads to the disease known as *delirium tremens*, which so frequently terminates the existence of drunkards.

94. Behind the fore-brain, and quite covered in by its lobes, is the mid-brain, almost entirely made up of ganglionic grey matter, and intimately connected with the nerves of sight and other sensation. In fishes this is much the biggest part of the brain. Behind this again, and not closed in by the great hemispheres, though overlapped by them, is the hind-brain. This has two parts, the *cerebellum* (an out-growth like the cerebrum), and a lower part called *medulla oblongata.* The cerebellum is about a sixth of the size of the brain proper, and is seated at the back of the skull, and divided from it by a thick membrane, called the *tentorium.* Like the lobes of the fore-brain, it consists of both white and grey nervous matter. The white matter is so distributed as to give it the appearance of a shrub or little tree, which has been fancifully named *arbor vitæ*, the tree of life. The *medulla oblongata* is a mass of nervous matter connecting the spinal cord with the great mass of nerve matter in the skull called "brain." From the base of the brain are given off various nerves, whose branches pass through holes in the skull, and reach either the organs of special sense, or the muscles and skin in the neighbourhood of the head. The medulla oblongata also gives off nerves within the skull. The spinal cord runs from the brain through the great hole (*foramen magnum*) at the base of the skull, in a canal made by the union of the vertebræ or separate bones of the

back. This is called the *spinal canal.* The spinal cord or marrow consists of grey and white nervous matter, of the same kind as that in the brain. The grey matter is found in the inside of the spinal cord, and the white matter is outside.

95. The principal nerves of the body are given off from the brain and spinal cord, and belong to what is called the *cerebro-spinal nervous system.* This is to distinguish them from that other set of nerves which are called the sympathetic, and which are found forming a network of nerves on each side of the body, from the neck to the lower parts of the body. This system of nerves is composed of a series of ganglia, which are connected together by nervous cords and twigs, and constitute the two great *sympathetic nerves.* The twigs of these nerves interlace freely with those passing from the brain and spinal cord. The appearance of the nervous matter of the sympathetic, under the microscope, differs from that of the cerebro-spinal system, in having many more nerve-cells and soft nerve-fibres, which are easily distinguished by the absence of a dark outline. Small twigs of this nerve are sent to the whole of the blood-vessels and to the minute capillaries, and by this means the whole of the organs of the body are brought within the control of the nervous system.

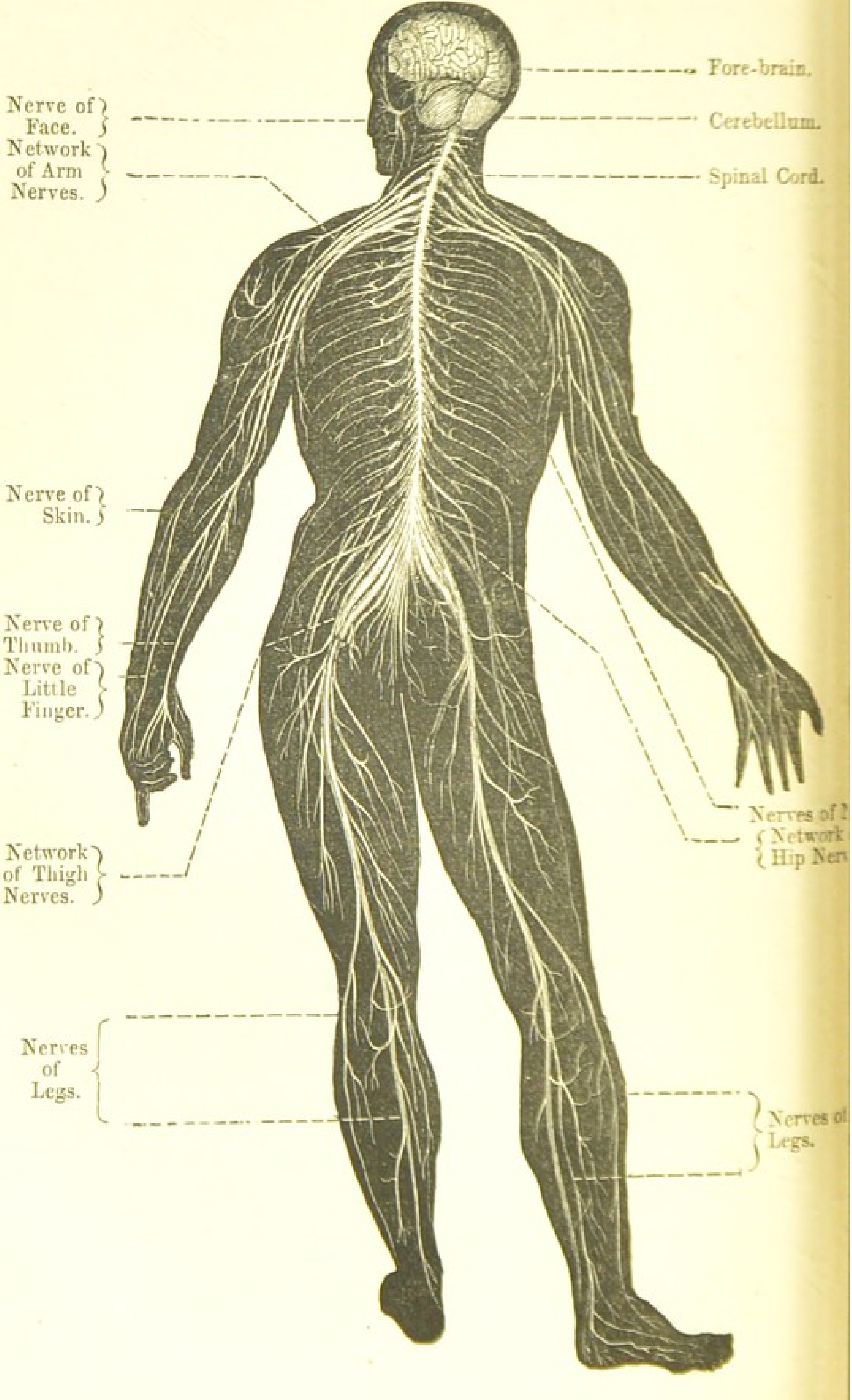
96. The nerves that come from the brain and medulla oblongata are all numbered, and as they pass out on each side of the brain they are called pairs. Thus we have nine pairs. The *first* pair are the olfactory nerves, which divide into a number of small twigs, and pass through a sieve-like bone at the top of the nose, and are distributed to the mucous mem-

brane of the nostrils. The *second* pair are the optic nerves, which pass through holes at the bottom of the sockets of the eye-balls, and are expanded into a delicate nervous membrane called the *retina*, which lies at the back of each eye. The *third*, *fourth*, and *sixth* pair of nerves are distributed to the six muscles of the eye, whilst each great fifth nerve divides into three branches, one giving common sensation to the upper part of the face, eye, and nose; the second to the upper jaw and teeth; the third to the lower jaw, and giving off too the nerve of taste. It is this nerve which gives us tooth-aches and face-aches. The *seventh* pair of nerves are singular; they have two branches, one of which goes to the ear, and receives impressions from the waves of sound, producing hearing, whilst the other branch goes to the face, and is a motor nerve, giving the wonderful powers of expression to the human face. The *eighth* pair have each three branches, which are distributed to various important organs; they descend down through the neck, giving branches to the tongue and the mouth, the lungs and the stomach, and having connections with the sympathetic nerve. They take their origin in the medulla oblongata. Below these important nerves originate two others within the skull, called the *ninth pair*, the branches of which go to the muscles of the tongue, and are the source of its movements.

97. The spinal cord, in its course down the spinal canal, gives off thirty-one pairs of nerves. These nerves are all of one kind, that is, they are nerves of common sensation and motion. They are distributed to the skin of the trunk and extremities, producing the common sense of touch, and to the muscles, pro-

PLATE XII.

Fig. 34.



EXPLANATION OF PLATE XII,

Fig. 34,

Representing the Cerebro-spinal Nervous System, and referred to in paragraphs 95, 96 *and* 97.

This diagram illustrates the whole nervous system with the exception of the sympathetic nerve (¶ 95). Above is represented the hind part of the fore-brain, and the exterior of the hind-brain, represented by the cerebellum, is seen. The mid-brain is concealed. The spinal cord is exhibited giving off its thirty-one pairs of nerves and is seen passing down from the brain. The spinal cord in its course gives off both nerves of sensation and volition, which are bound up in the same sheath. These are distributed to the arm and run down to the tips of the fingers, where the greatest development of the functions of sensation takes place.

On arriving at the pelvis the spinal cord divides into two sets of nerves, one of which goes to the right and the other to the left. These are distributed to the legs and the toes. The nerves of the spinal cord are not only distributed to the internal structures giving rise to the functions of sensation and motion, but they are especially distributed to the skin, where they become the nerves of common sensation or touch. The whole surface of the skin is sensitive as the result of the distribution of the nerves of sensation from the spinal cord.

ducing motion. Each of the spinal nerves has two roots in the spinal cord, the one coming off from behind, containing the nerves of sensation, and others passing off from before, forming the nerves of motion. These roots unite together, forming a single nerve, which possesses both the property of carrying up sensations and bringing down volitions. For the discovery of this great fact in the action of the nerves, we are indebted to Sir Charles Bell. He showed that when the posterior roots of the nerves were cut, an animal lost the power of feeling, and that when the anterior root was cut it lost the power of motion. The spinal cord and the nerves which issue from it, form what is called an *excito-motor* nervous system, and although the sensations produced on it may be, and generally are, recognised by the brain, and the motor nerves are acted on by the will, it nevertheless can act entirely independent of the brain. The brain of a frog or a turtle can be removed without pain to the animal, and if this is done, and the animal is pinched or irritated in any way, it exhibits movements in the corresponding nerves. Thus, a frog will jump when its legs are pinched, although its head is cut off.

98. The nerves generally terminate by means of loops in the various parts of the body to which they are sent. From these loops again little processes are sent into the tissues around the nerves. Sometimes the nerve terminates in a minute sac or capsule. This is especially the case in the nerves sent to the fingers, and this arrangement is found also in other parts of the body. These minute swellings are called *Pacinian bodies*, after Professor Pacini of Pisa, who

first accurately described them. Their use is undoubtedly connected with the more delicate tactile function that is found to exist in the tips of the finger in man. A wonderful modification of nervous structure is seen in the electric organs of some fishes. A peculiar apparatus composed of hexagonal plates is placed on each side of the fish, and on this arrangement of plates the nerves are distributed. The animal has the power through this apparatus of discharging its nervous force in the form of electricity. It is clearly seen from the history of these animals that the nervous force can be transformed into electrical force.

99. Of all the parts of the nervous system the brain is most important. All other parts of the nervous system terminate more or less directly in the brain. In proportion to the rest of the nervous matter in the body, it is larger in man than in any of the lower animals. It is the function which the brain performs that distinguishes man from all other animals, and it is by the action of his brain that he becomes a conscious, intelligent, and responsible being. The brain is the seat of that knowledge which we express when we say *I.* I know it, I feel it, I saw it, are expressions of our individual consciousness, the seat of which is the brain. It is when the brain is at rest in sleep that there is least consciousness. The brain may be put under the influence of poisons, such as alcohol and chloroform, and then the body is without consciousness. From these and other facts the brain is regarded as the seat of *consciousness.*

100. Not only is the brain the means by which the impression of our own existence is made evident, but it is the recipient of all those impressions from with-

out which are called *ideas.* Thus we see with our eyes a particular colour, and it is as it were registered in the brain in the form of an image or idea. In the same way we feel a hot body, and we get the idea of heat, and so on with our other senses; and the act by which we apprehend the properties of bodies outside of us, is called *perception.* It is in this way that man, by the exercise of the nerves of smelling, seeing, hearing, tasting, and feeling, is enabled to accumulate ideas in his brain. Of all these ideas which are thus taken up and registered in his brain, he is made conscious by the same organ, and thus man becomes a *conscious intelligent* being.

101. Although the brain is said to be the seat of consciousness, it must not be supposed that man has no consciousness without the brain. Man is a spiritual as well as a material being; and lying beneath all natural forces is the soul of man. This is the recipient of all that man gets to know by the material instincts of his body, and survives the destruction of the human frame. It is this spiritual part of man's nature that carries on his identity from month to month, and year to year, and makes him to know that he is the same individual from the day of his birth to that of his death. The composition of the organs of man's body are constantly changing. A quantity of matter, equal to the weight of the whole body, is lost in forty days; hence we may conclude that whilst the matter is constantly passing away from the body, the human spirit remains, retaining the consciousness and carrying on the existence of man from this world to another.

102. When ideas have been received in the brain, they do not remain passive. The brain has the

power of recalling the ideas it has received in the past. This faculty is called *memory*, and upon this faculty much of the power of man over the external world depends. It is thus that he becomes more learned the longer he lives; and that life in old age is filled with the recollections of the past. When we consider the vast amount of knowledge exhibited by the intellect of men of mature age in the vigour of health, we cannot but feel astonished at the power possessed by this material organ of man's highest life. Not only has man the power of recalling the ideas that have been once impressed upon his senses in the same order in which he has received them, but he has the power of combining these ideas, and making them to assume new forms, such as never were actually presented to him by his senses. This faculty of combining ideas, and reproducing them in new forms, is called *imagination*, and lies at the foundation of the arts of poetry, music, painting, and sculpture. The result, also, of the activity of the brain is that arrangement and comparison of the ideas which we receive from without, and the arrival at conclusions which are called *judgment* and *reasoning*. Whatever qualities, in fact, can be properly attributed to the human mind, must have their source in the brain.

103. When ideas are received into the mind, they frequently produce impressions, which are called feelings and desires. These feelings, some of which are called emotions and passions, all have their seat in the brain. Amongst these feelings is that of love—the love of the sexes, the love of children, the love of home, benevolence, the love of man, self-love, the love of approbation, the desire of doing right, conscience,

the feeling of adoration, and the recognition of a good and allwise God. There has been a dispute amongst writers upon the nature of the mind of man, as to whether certain ideas, such as those of the existence of God, and a sense of right and wrong, are innate or are acquired by the action of our senses upon the external world, and by instruction from others. Whatever be the view taken of this great philosophical question, all are agreed that the brain is the seat of the thought, and connected with these ideas. The result of the action of ideas on the brain, in connection with the emotions, produces those effects in the muscular system which are called voluntary movements. When man is conscious of these motions, and determines upon them as the result of the action of his ideas, he is said to exercise his *will*. The brain is, therefore, the true organ of the will; and a man is regarded as responsible for his actions, on account of his being able, by his will, to choose between different courses of action. It is of the utmost importance of man so to educate his mind, that his intellectual judgments may control the emotions and passions which too often influence his conduct.

104. Although the functions of the brain are thus complicated, there is little trustworthy evidence to show that any particular parts of the brain are devoted to the performance of especial functions beyond the general distribution of sensation and consciousness. (92, 93). A few years since a system of mental philosophy was introduced, under the name of *phrenology*, the first principle of which was that the brain was a congeries of organs. These organs were

thirty-two in number; and each organ was supposed to be devoted to a separate faculty. It was said that the size of these organs could be told by the conformation of the skull; and thus that the general character and tendencies of individuals could be judged by the size and form of their heads. After many years of observation the experience of physiologists has not confirmed these views; and whilst the simplicity of the arrangement of the various faculties of the mind introduced by this system are to be commended, the statement that each faculty of the mind has an organ in the brain cannot be entertained. At the same time, it should be stated that a considerable amount of evidence has been produced to show that the front portion of the left hemisphere of the fore-brain is connected with the function of language.

105. From the evidence of the fact that one side of the brain may be diseased or injured without affecting the general functions of the brain, it would appear that each hemisphere of the brain is capable of performing all the mental acts. One of the great proofs that the brain is the organ of the mind is seen in the fact that, in proportion to its size, all other circumstances being alike, it is capable of performing its functions. Thus, the brains of those who have made an unusual impression on their age, have been found to be large. The brain of Cuvier, the French anatomist, weighed sixty-four ounces; that of Dr. Abercrombie, an eminent Scotch physician, sixty-three ounces; that of Dupuytren, the great French surgeon, sixty-three ounces. On the other hand, the observed weight of the brain of acknowledged idiots has been from nineteen

to twenty-two ounces. The weights of the brains of the chimpanzee and the gorilla have been found to be about ten ounces. The average weight of the human brain in male and female is about forty-eight ounces. The average weight of the female brain is about three ounces less than that of the male.

106. As the brain is the most important organ of the human body, so it should be an object of the utmost solicitude to keep it in perfect health. The muscular and nervous systems differ from the heart and lungs in requiring rest. The brain of man is so constituted that in order to perform its functions it must have periodical seasons of entire rest. This rest we call *sleep*. Not only does sleep appear to be necessary for the purpose of resting the brain and nervous system, but it is during this period that the wear and tear of the nervous matter is repaired. Without sleep the brain is worn out, and persons have been known to die from the effect of being forcibly kept awake. The quantity of sleep required varies much with different individuals, and also with age and amount of work done with the brain. The average amount of sleep required by adults is eight hours of the twenty-four. It is recorded of many persons that they have been able to do with much less, but they have died early. Sleep and death are twin sisters, and if the one is robbed the other will have to be paid. Infants sleep all day long, and old persons require more sleep than young ones. Persons who work with their brains at mental pursuits require more sleep than those who work with their muscles. The history of all hard students who carry their hours of study over midnight, and rise early in the

morning, shows how dangerous it is to try and cheat nature out of her necessary rest.

107. When sleep is not obtained, it is a sure sign that something is wrong in the body, and persons under most circumstances should make a searching inquiry for the cause. Although sleep is induced by taking certain drugs, as opium, hemlock, henbane, and others, it is never wise to have recourse to these agents unless under skilled medical advice. Alcohol (23) sends persons to sleep at first, but if the dose of alcohol is repeated, it brings on changes in the brain which end in a disease called *delirium tremens*, the chief characteristic of which is the utter inability of the person affected to obtain sleep. Mental anxiety, by whatever cause produced, will tend to deprive the brain of sleep. It often happens under these circumstances that the brain not getting properly nourished, its functions give way, and *insanity* is produced. In the majority of instances where persons make away with themselves, it is in a fit of insanity produced by sleepless nights. For temporary wakefulness many devices have been proposed. The voluntary direction of the attention to some sensation will often incite sleep, such as listening to the ticking of a watch, or the dropping of water, or repeating well-known lines of poetry, or recalling past scenes. Sir Thomas Brown says he found it a most effectual soporific to repeat some verses on which the well-known "Evening Hymn" is founded.

108. The occurrence of *dreams* during sleep is a curious and interesting phenomenon. They appear to arise from the action of ideas in a semi-conscious state of the brain. During deep sleep it appears

there is little dreaming, but when the brain is sufficiently refreshed and recruited by repose, a condition comes on in which the brain recalls its ideas in various fantastic forms. That consciousness during the time of dreaming is not fully alive, is seen by the little impression that is made on the mind by the grotesque absurdities which are frequently presented. Although so much superstitious importance is attached to dreams, there is nothing to prove that, during this half-waking state of the brain, any knowledge can be gained further than can be obtained in the waking state. There is no proof whatever that the brain in its state of sleep has the power of acquiring or affording any information of a kind different from that which it possesses in the waking state. The practice of attaching any importance to dreams should be dismissed, as altogether unjustified by experience, or by our knowledge of the nature of the functions of the brain.

109. Whilst, however, no significance is to be attached to dreams, there are certain conditions of the brain occasionally present during sleep, that are of high interest. Thus, persons walk in their sleep, and are said to be *sleep-walkers*. It is well known that some persons will exhibit during sleep a consciousness of what is going on around them, without being aware of this state when they awake again. They will walk about the house, reply to questions, and exhibit an active interest in what is said to them, but when awakened they will know nothing about what has taken place. When they go to sleep again, and again assume this state, they will recollect all that had gone on in their former sleep-walking state. They seem

to have a double consciousness, and, as it were, a sleeping and a waking life. What is most curious about this state is, that it can be artificially produced. The "mesmeric" condition of which we have already spoken (92) seems to differ but little from this sleep-walking state which occurs naturally.

110. The actions of persons in this condition are determined by the fact of one idea suggesting another. This is called the *association of ideas*. In our waking state, the will more or less controls this association, although every one is aware of a condition of the mind which is called *day-dreaming*, in which the will as it were lets go its control of the ideas, and allows them to go wandering where they like. In sleep-walking, also called the *mesmeric* state, that condition of the brain which enables it to exercise will, is entirely lost, and the individual becomes the victim of another's will by the suggestions made. The absurdities of the exhibition of what is ignorantly called electro-biology, including table-turning, may be thus explained, as also other similar occurrences, in which people are puzzled by the results of their own actions performed unconsciously.

111. From the previous survey of the nature of the human brain, it will be seen that to ensure its healthy activity, all its functions should be fully developed, and especially that the emotions and feelings should be brought under the control of the Will. This is the first object of *education*. The infant is more or less under the control of its feelings, but, as its intellectual powers are developed, it gradually gains the power of controlling its emotional nature. Next to the development of the Will the object of educa-

tion should be to develope the intellectual powers of the brain; to train it to observe external objects accurately, and to reason upon them correctly, so that the individual may arrive at right conclusions, and act accordingly. From defective education, persons constantly grow up incapable of controlling their emotions and passions, and exhibit all the characteristics of vice and crime. In too many instances the feelings and emotions altogether control the intellectual judgments, and the mind becomes permanently disturbed. This condition is called *insanity*. The first tendency of the feelings to overpower the judgment should be controlled, and the great end of all education should be to make of man a being who both knows, and at the same time can will to do, that which is right and best for his own and others' happiness.

CHAPTER IX.

ON THE ORGANS OF THE SENSES.

112. We have seen that the brain derives its ideas from impressions produced upon the nerves. These impressions are derived from various sources; and the nerves are so constructed, that they may gather information, as it were, through the activity of the various forms of matter and force which exist in the external world. It is said that man possesses five senses; and these are very appropriately called the "five gateways of knowledge." These senses are the sense of Touch, of which the hand may be said to be the special instrument; the sense of Sight, of which the eye is the organ; the sense of Hearing, the function of which is performed by the ear; the sense of Smell, which resides in the nose, and the sense of Taste, belonging to the tongue.

113. Of these senses, that of touch is the most diffused. This sense resides not only in the hands and fingers, but the nerves which minister to it are spread over the whole body; and thus it is called the common sense. It usually acts through the termination of the nerves in the skin; but wherever *pain* is felt in the body, it results from the action of the nerves of sensation. Some of the nerves which proceed from the brain, and all those which proceed from the spinal cord are susceptible of impressions from

being brought in contact with external bodies. It is thus that we discover the hardness or softness of bodies, their heat or coldness, their roughness or smoothness; and when the sense of sight is deficient, that of touch supplies a large amount of information, by which the minds of those who are blind are instructed. Combined with the action of the muscles which supplies to the brain ideas of resistance, the sense of touch is the great minister to man's wants as a civilised being. It is by means of the muscular sense, and that of touch, that the hand of man is educated to perform the various acts which distinguish him from the lower animals. The hand is employed in all the great occupations of life. The working man labours with his hand; with it he uses the saw, the chisel, the hammer, the spade, and the plough. With the hand the artist paints, and the author employs his pen. All the machinery of our manufactories is made by the hand, and superintended by the hand, and all domestic industry is carried on by the hand. The discoveries of the chemist and natural philosophers have all been made by the use of the hand. The nerves which are thus active in the hand, are distributed to all other parts of the skin; and every portion of the skin may be regarded as a part of the organs of touch. Every part is not, however, sensitive alike. If we take a pair of compasses, and place them in different parts of the skin, it will be found that the two points are distinguished very differently on different parts of the body. The two points of the compass will be distinguished at $\frac{1}{24}$th of an inch apart on the tongue, at $\frac{1}{6}$th of an inch on the lips, $\frac{1}{12}$th on the tips of the fingers, and at $\frac{1}{2}$ of an inch on the great toe. Sometimes the sense of touch is lost. Every one knows that when the arms or legs are pressed on for some time, a "prickling" sensation is felt. This arises from interference with the nerves of sensation; whilst in some diseases the communication between the nerves and the spinal cord is destroyed, and then *paralysis* or palsy takes place.

114. The other four senses are called special senses; of these the most important is the eye. The eye is really a most perfect optical instrument. It is so constructed, that most perfect images of all external objects are, as it were, felt by the nervous system. In the lowest animals the eye consists of a twig of nervous matter, rising from a ganglion; and over this may be placed a little lens, which, collecting together the rays of light, forms a bright spot, which is perceived by the nervous twig on which it is impressed. As we pass up from the lowest animals, the eye becomes more complicated in those arrangements by which exact vision is secured, till we come to man, where we find this organ exhibiting its most perfect condition. For the purpose of understanding the structure of the eye, it is worth while to procure the eye of a dead animal, such as a sheep, or an ox, by dissecting which, its general structure can be easily understood. By examining, however, our own eyes in a glass, or another person's eye, we can get to know how wonderful an instrument it is. The whole of the seeing parts of the eye are contained in a round tough case or bag, which is sunk in the sockets of the skull. Passing from the brain, through a hole at the bottom of the socket, is the optic nerve, which pierces the bag of the eye, and penetrating its interior, spreads itself upon the inner

PLATE XV.

Fig. 41.

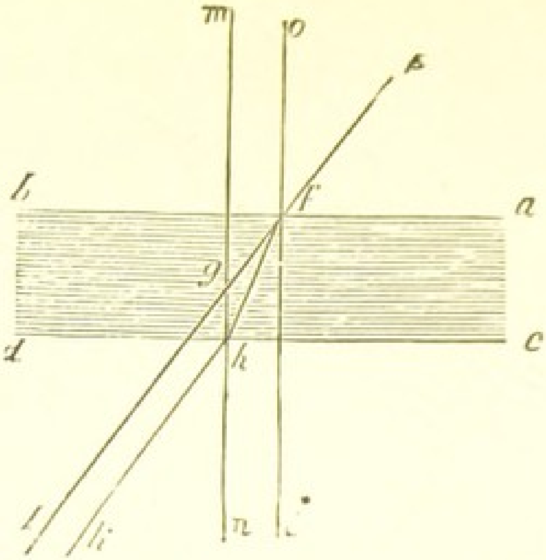
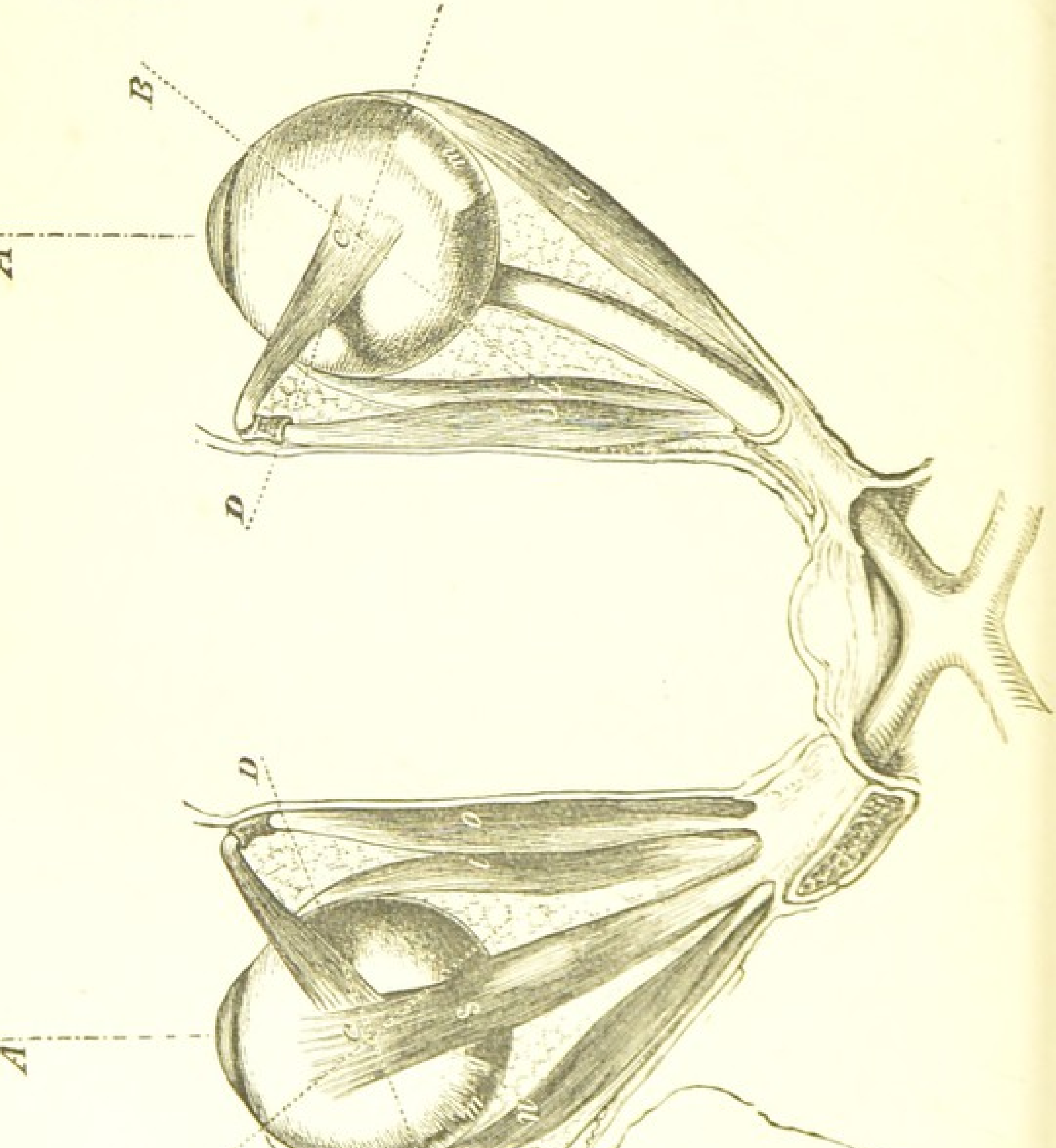


Fig. 42.



EXPLANATION OF PLATE XV,

Illustrating the Structure and Functions of the Eye, referred to in paragraphs 114, 115, *and* 116.

Fig. 41 is a diagram representing what is called the refraction of light. *a b c d* is a plate of glass. If a ray of light, *p f*, strikes the glass, instead of passing in a straight line through the glass from *f* through *g* and *l*, it is bent down to *h*, and passes on to *k*. It is thus permanently bent. The lines *e i* and *m n* represent the extent to which the ray of light has been bent or refracted. The lens in Fig. 40 has been the means of bending the rays of light so as to produce the effect there observed.

Fig. 42 represents the external structure of the eye. The optic nerves are seen passing to the interior of the ball of each eye. At the base of the ball, where they terminate, they expand into a fine network of nervous matter, which constitute the *retina*. The eyeballs are placed in the sockets of the skull, and are moved by means of six muscles. These muscles are marked at *u*, *s*, *i*, *v* and *e*. *m m* is the sclerotic membrane, which is a thick fibrous coating and covered with the membrane called the conjunctiva. In front the sclerotic gives place to the cornea, *A*, *A*, which is a very thick membrane, but is transparent and allows the rays of light to pass into the interior of the eye.

surface, forming a network of nervous matter, called the *retina*. It is upon this network that the picture of external objects is thrown by the aid of the other parts of the eye. The picture thus formed is as much felt by the retina as an object that is touched is felt by the finger. Not only is the form and shape of external objects thus perceived, but the most delicate shades of colour are appreciated. These pictures of external objects are formed in both eyes at the same time, and it is by the action of the two eyes upon one object that we get the idea of the rotundity of objects, and their relative distances from each other.

115. If we now examine the ball of the eye, we shall find that it consists of a membranous bag, which is everywhere opaque, except in front, where there is a transparent membrane called the *cornea*. This membrane, like a watch glass, is convex in front, and concave behind. Through this transparent membrane the rays of light penetrate into the inside of the ball of the eye. Behind this membrane is a quantity of water, called the *aqueous humour*, which, when the cornea is punctured, escapes. Within the cornea is seen the coloured part of the eye, in the middle of which is a dark-looking opening into the interior of the eye, which is called the *pupil*. If we look at a person's eye, it will be seen that this little opening expands or contracts, as the eye is exposed to the light or protected from it. This expansion and contraction occurs in a delicate membrane, which is always coloured, and gives the various colours to the eye. It is called the *iris*. It is, in fact, a sort of circular curtain, which, by folding up and letting down, is employed for regulating the quantity of light in the interior of the eye. It contracts when

the light is strong, and dilates when the light is weak. Behind the pupil formed by the iris is situated the *crystalline lens*. This is a doubly-convex transparent body, about the size of a French bean, and is important in forming the pictures which are thrown upon the retina. The lens of the eye can be easily imitated in glass, and exactly the same effects can be produced. This is done by an instrument called a *camera obscura*, in which a lens is used for bringing the picture of external objects on to a surface in a darkened chamber, which can then be examined by the eye. This is the instrument used by the photographer for taking portraits, and making pictures of buildings and scenery. The photographer's method of forming pictures has always been exercised by the human eye; his special art consists in rendering the pictures he obtains permanent by chemical means.

116. If we examine still further the eye, we shall find that the crystalline lens rests upon a semi-liquid mass, which occupies the greater part of the hollow of the eye-ball. This is called the *vitreous* humour, and fills the chamber of the back of the eye. If we look into a living human eye, through the pupil, we can discern the picture that is painted on its back, and thus discover what the individual sees. This picture lies upon a dark surface, as the walls of the eye are painted black. This is done with the object of making the picture more distinct; for just as the photographer must make his sun-picture in the dark, so must the sun-pictures on the eye be made in a dark chamber. If we examine the interior of the eye of an animal, we shall find that the inside chamber of the

eye is covered over with a *black pigment*, consisting of very minute cells containing carbonaceous matter. Sometimes this pigment is absent in the eyes of men and animals. Such individuals see very imperfectly; and the blood-vessels, with which the eye is abundantly supplied, can be seen through the pupil lining the bottom of the eye, giving it a red appearance. Such persons have also a deficiency of colouring matter in other parts of the body, and their hair is white, whence they are called *albinos*.

117. The outside, as well as the inside of the eye, is supplied with minute blood-vessels. Those on the outside of the eye run along a very delicate membrane, which covers that part of the eye which is called the white, and the cornea. When anything gets into the eye, the blood stagnates in the vessels, and they can be seen traversing the white of the eye in all directions. This also takes place when the eye is inflamed, and what is called *ophthalmia* occurs. The eye becomes inflamed by exposure to cold, or by looking at an intense white light. Thus persons have been known to get ophthalmia during the long prevalence of snow. Among the defects of the eye are those called *short sight* and *long sight*. When a person is short-sighted, and has to put his eye closer to an object to see it than other people, it arises from the cornea being too rounded, and the pictures passing through it are formed, not immediately on the retina, but in front of it. This defect is removed by wearing glasses—spectacles, by which the condition of the cornea is rectified. So with long sight, the cornea in that case is too flat, and the picture is formed beyond the retina; but glasses

can be worn by which this defect may be remedied. There is no need for alarm about these conditions of the eye; and no fear need be entertained of using those forms of glasses which most efficiently rectify the defect.

118. The eye is unfortunately liable to many diseases of its internal structure which render it utterly useless, and persons are then said to be *blind.* Some persons are born with these structural defects, and remain blind during the whole of their lives. One common form of these diseases is *cataract,* which consists of a thickening of the lens, and the rays of light are then prevented from passing on to the retina. This disease can, however, be often remedied by an operation, which consists in removing or breaking up the lens, and many persons born with cataract have thus been restored to sight. The most irremediable forms of disease of the eye are those which affect the optic nerve. This nerve, like others, is subject to paralysis, and when this comes on, no picture on the retina is perceived, and the person becomes hopelessly blind. This disease is called *amaurosis.* The poet Milton was thus afflicted, and often refers in his poems to his sad condition—

> "Wisdom by one entrance quite shut out."

119. Outside, the ball of the eye is surrounded with means for preserving its structures and enhancing its functions. The *eyelids* cover the eyeball, and by their ready winking preserve it from the frequent attacks of insects and the alighting upon the cornea of particles of dust. On the ball of the eye, hidden from view by the lids and sockets, are a variety of

PLATE XVI.

Fig. 43.

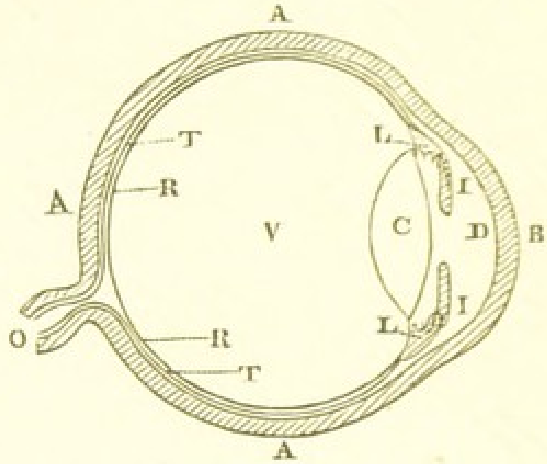
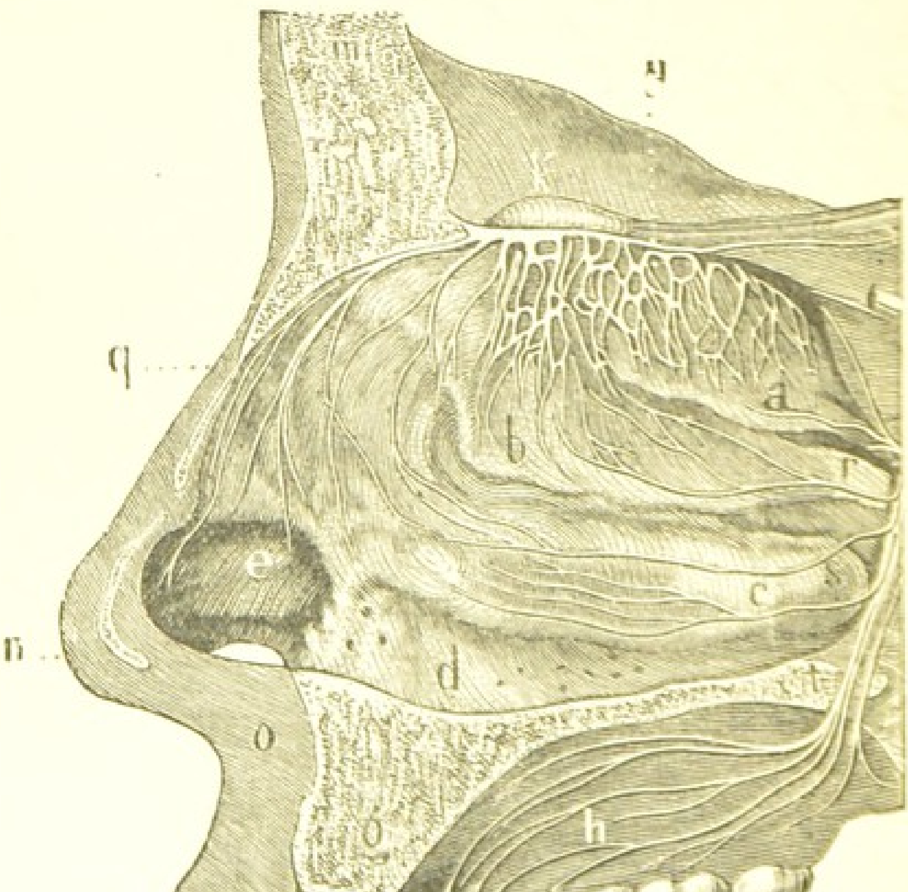


Fig. 44.



EXPLANATION OF PLATE XVI,

Representing the Structure of the Eye and Nose, referred to in paragraphs 115, 116, 117, 118, *and* 125, 126, 127, *and* 128.

FIG. 43 is a diagram of a section of the interior of the eye, with its various coats and membranes. A, A, A represents the sclerotic membrane and conjunctiva; B is the cornea; C is the crystalline lens; D the anterior chamber, containing the aqueous humour; I, I is the iris. The aperture between the section of the iris represents what is called the pupil of the eye. R, R is the retina, which is the expansion of the optic nerve; T, T is the choroid membrane, composed principally of blood-vessels, with which are mixed black pigment-cells, which makes of the posterior cavity of the eye a dark chamber, by means of which the pictures produced on the retina at the back of the eye become more intense and thus recognition more obvious. The absence of the pigment-cells produces what is called albinism. L, L is the ciliary muscle, which lies at the base of the iris; V represents the vitreous humour, which fills the posterior chamber of the eye.

FIG. 44 represents the interior of the nose. *a*, *b*, *c*, *d*, *r*, *e* indicate the interior of the nose, which is covered by a mucous membrane; *n* represents the nose, and *e* the wing of the nose; *q* are the nose-bones; *o* is the upper lip; *g* is a section of the upper jaw-bone; *h* is the upper part of the jaw, or hard palate; *m* is the inner part of the skull; *k* is the ganglion or bulb of the olfactory nerve in the skull, from which are seen the branches of the nerve, after having passed through the cribriform process in the skull, passing in all directions to the nose. The diagram represents below the teeth in the upper jaw.

muscles, one end of which is attached to the eye, and the other to the solid bone of the socket. It is by means of these muscles that the eye moves upwards, downwards, and to either side. Sometimes these muscles are contracted or act irregularly; a person is then said *to squint.* This defect is now, in many cases, cured by an operation, by which the muscles are restored to their equilibrium. At the outer side of each eye above is a little gland called the *lachrymal gland*, which is constantly secreting a saline fluid which, passing over the front of the eye, washes it clean, whilst the eyelid, as it were, wipes it dry by forcing the liquid thus used into a little drain pipe, which carries the fluid into the nose. This is one reason for the constant use of the pocket-handkerchief. Sometimes the lachrymal gland secretes more liquid than the nose can carry off, and it drops out of the eye on to the cheek, and the drops are called *tears.* There is a curious connection between certain mental states and this little gland, so that when persons are unhappy or disappointed, or angry, it pours out a large quantity of this liquid, which drops down their cheeks and they *cry.*

120. A little reflection will teach us that the eye is one of the most important inlets of our knowledge, and we should be careful to keep it in health, and cultivate its great powers to the utmost. In order to keep it in health, it should not be exposed to cold draughts, either sleeping or waking, nor should it be intensely employed in gazing on strong or bright colours and lights. In all work where particles of iron, steel, or other solid matters are liable to get beneath the eyelids, the eyes should be protected with a shade. Like all other organs the eye may be

educated, and its powers developed. A natural education of the eye goes on with the child. At first things are seen very indistinctly by the infant, and it cries to have the moon in its hands, as though it was close by. As the child grows older it appreciates the relative distances of objects, and it is by cultivating this power of the eye, that it becomes the most useful organ of our senses. One of the greatest means of cultivating the power of the eye is by teaching the arts of drawing and painting. By thus using the hand as the instrument of the eye, the faculty of observing is cultivated, and gradually the eye learns to see and to observe the great variety of forms and the colours in external objects. Another mode of educating the eye, is to describe accurately in writing the forms, colours, and habits of external things. There is no pursuit more valuable and interesting in this respect than the study of natural history. Children should be early encouraged to observe the forms, colours, and structure of plants and animals, and the habits of insects, fish, birds, and other creatures. It is in this way that the eye can alone be educated for performing practical work in an efficient manner. In a large number of our British manufactures the highest excellence of the work can only be attained by the workman being early skilled in the use of his eyes upon the forms and colours which are observed in the natural world.

121. Next to the eye, the ear is the most important of the organs of the senses. So great is the information conveyed to the brain by the action of the ear, that some writers have contended that the loss of the sense of hearing is even greater than that of sight.

PLATE XVII.

Fig. 46.

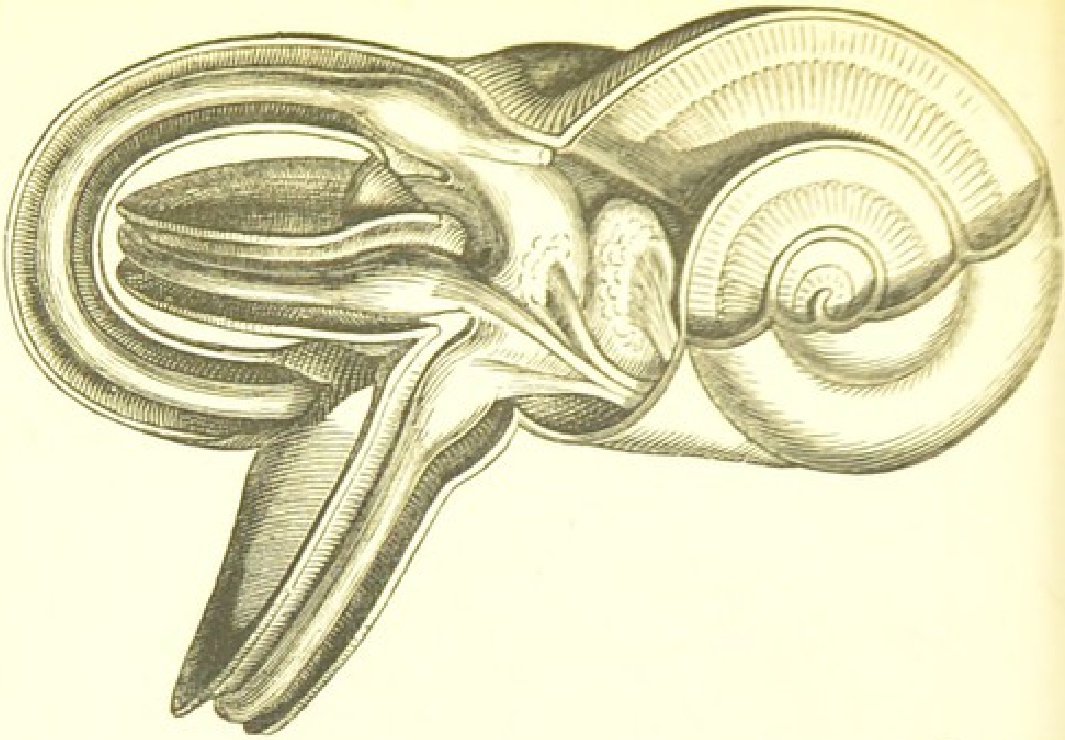


Fig. 45.

EXPLANATION OF PLATE XVII,

Illustrating the Structure of the External, Middle, and Internal Ear, and referred to in paragraphs 121 *and* 122.

Fig. 45 represents the inner, the middle, and the outer ear. The inner ear is contained in a portion of the skull called the petrous portion of the temporal bone. The external ear is composed of a gristly substance, and is so formed as to catch the vibrations of sound and carry them to the auditory passage, *a*. At the inner termination of the auditory passage is the tympanum or drum of the ear. The middle portion of the ear is a cavity which contains a series of little bones (*ossicula auditus*). These little bones are called the hammer, *d*, the anvil, *e*, and the stirrup, *f*. There is a smaller bone, which is not seen. The stirrup *f* is attached to the hole which communicates with the three semicircular canals seen to the right of the drawing. *o* represents a round opening which communicates with the *cochlea* or snail-shell process; *a* is the auditory nerve passing into the labyrinth or inner ear; *b* is the Eustachian tube, which communicates by an open tube with the throat.

Fig. 46 represents a section of the inner ear for the purpose of exposing the structure of the labyrinth. To the right the cochlea is laid open to show the position of the nerve, and with the semicircular canals is laid open. Between these two organs is a space which is called the vestibule, and here may be seen the auditory nerve passing to be distributed to the semicircular canals and the cochlea.

Whilst the intense undulations of matter which we call light, address the sense of sight, and the less intense undulations of matter which produce heat, are appreciated by the organs of feeling, it is the vibrations of the atmosphere in which we all live that are gathered up by the ear, and constitute the marvellous phenomenon which we call sound. In the lower animals an organ of hearing is almost always present; generally as a little bag full of liquid, which shakes with the sounds, and so affects the nerve placed in its walls. In fishes the ears are highly complicated with canals, and still more so in birds and reptiles; but it is in mammals only that it has an internal coil like a snail's shell. In man the ear is placed on each side of the head, and the nerves which convey the impressions of sound to the brain, are imbedded in the solid bonework of the skull. On opening the skull so as to see where the nerve of hearing on each side goes, we find, hollowed out in the solid bone, three curved tubes, called semicircular canals, and a spiral cavity continuous with them, and called the *cochlea*. In these curiously shaped cavities, which contain liquid, the nerve of hearing spreads out and forms a lining. Leading from this to the exterior is a large chamber called the tympanic cavity, between which and the external passage is placed the drum of the ear. From this also a passage leads into the mouth, which you can feel by blowing.

122. Whenever one body strikes another in the air, waves are produced, just as when we throw a stone into the water, a ring of waves is seen to surround the spot where it sinks. These waves of the air are conveyed by means of the external ear down a passage

which is called the external *auditory* canal. This passage secretes a little wax, to deter insects from entering it and interfering with its functions. The waves of the air having got to the end of this passage, strike against a membrane called the *tympanum*, or the drum of the ear. On the other side of the tympanum is a string of little bones, which convey the sound to the nerves which are hid in the bony canals of which we have before spoken. When the waves of the air reach the nerves of the internal ear, the mind takes cognisance of them, and what is called sound is produced. It is through this organ that man is capable of communicating with his fellow man by means of language (51).

123. Not only does the ear appreciate the delicate vibrations of the organ of voice, but the mind is so constituted as to take pleasure in certain harmonious relations of these vibrations, which are called *music*. When the waves of the air recur with a certain rapidity a musical *note* is produced. The fewer the waves, the lower the notes. As the waves produced are quicker and more numerous, the notes are higher. There are certain harmonies between the various notes, and when these are put into action, music is produced. Almost any vibrating body can be made into a musical instrument. Thus, air may be blown through a tube in the form of a whistle, a flute, a flageolet, or a clarionet, and the lower or higher notes are produced by blocking up certain holes with the fingers, which modulates the vibration of the air. The violin and the piano are instances of stringed instruments, the vibrations being produced by rubbing or striking the strings. Brass instruments are made of metal, the vibrations of which respond to the air, blown into them through the mouth.

All these instruments may unite together and form, by the sounds they produce, a concert. Of all instruments, however, the human voice is the most perfect, and the performer on it being capable of throwing into it his own feeling, *singing* is one of the most agreeable and pleasurable sensations to which the ear can submit.

124. The ear, like other organs, is subject to diseases. The external opening may be blocked up either by the accumulation of its natural wax, or by foreign agents. When deafness results from these causes, the ear should be syringed out with a syringe and warm soft water. The tympanum or drum is sometimes broken by violent noises, or becomes ulcerated by disease, and the little bones of the ear are lost. This does not occasion perfect deafness. It is when the auditory nerve is diseased, or becomes paralysed, that deafness comes on. This nerve, like others, may be disordered by a general want of health in the system, and its condition removed with restoration to health. When, like blindness, deafness comes on from palsy of the nerve, little, if anything, can be done to remedy the terrible deprivation. Some children are born deaf, and to such, another calamity is added, for they are also dumb. Never hearing "the sweet music of speech," they cannot imitate it, and only exercise their voice in inarticulate noises. Schools are opened for the instruction of such persons by the aid of the eye, and they are thus enabled, to some extent, to make up for the deficiency of hearing. They are taught to converse by the aid of their fingers, which are used instead of sounds to communicate ideas. Some successful attempts have

been made lately to lead dumb persons to speak, by teaching them to observe the movements of the tongue and lips during the speech of others.

125. The two remaining senses, those of taste and smell, are very closely connected in use, though really fundamentally distinct. In man the smell is quite rudimentary, and is only accessory to taste: but in lower animals smell is as important and useful a sense as sight or hearing. From underneath each hemisphere of the brain there runs a nerve which, dividing itself into a number of minute branches, pass through a sieve-like bone, at the upper part of the nose, and distribute themselves in the mucous membrane of the interior of the nose. This is the *olfactory* nerve, the nerve of smell. It takes cognisance of minute particles of matter, which are diffused throughout the atmosphere, and which are carried through the nostrils with the air which we breathe. The function of smell seems to be developed in the lower animals to a much greater extent than in man. Thus most of the mammalia are led to their prey and their food by the function of smell. The dog is trained to exercise this faculty, and he is used by man to trace the game he pursues. The dog called the bloodhound has even been used to track the footsteps of man, when he has escaped from pursuit or persecution into the desert.

126. The organ of smell is susceptible of pleasant and unpleasant impressions. The pleasant smells are called *perfumes*, and they are capable of affording great pleasure to the mind. The nations of antiquity cultivated the sense of smell much more extensively than the modern inhabitants of Europe. We read

constantly in the Bible of the use made of pleasant smelling gums and resins, such as frankincense and myrrh, and in the services of the Temple amongst the Jews, the burning of sweet incense was a constant practice. The Greeks and Romans anointed their bodies with oils, perfumed with the sweet smelling scents from plants. The art of the perfumer is, however, carried to great perfection at the present day, and he selects the most agreeable scents from plants and animals, and combining these, forms the pleasant compounds which are used for perfuming clothes, soap, and a variety of other articles of domestic use. From recent chemical researches it appears that the volatile oils which give odours to plants and other bodies of a similar nature, such as camphor, have a power of destroying animal poisons (56). It is a belief of this kind that has led to the employment of strong-smelling compounds, such as "aromatic vinegar," and also of camphor, as a means of preventing the spread of contagious diseases.

127. But whilst the sense of some smells is grateful to the mind, the impression of others produces disgust. This sense of the disagreeable in scent is also seen in the lower animals. Many of them instinctively avoid certain smells, just as they are attracted by others. We may attract animals by one set of scents, but we can drive them away by others. They seem to be warned against eating certain kinds of dangerous food by its smell. In the same way man is guided and warned by his sense of smell. He thus avoids putrid food, because of its unpleasant smell. All forms of decomposing animal and vegetable matter give out gases which are disagreeable to man's

sense of smell, and he is warned by this sense of the danger in which he is placed, by living in contact with substances which give out these unpleasant gases. It is not always that an unpleasant smelling gas will injure the body if taken into the lungs, but it should always be recollected that there is danger lurking about where the atmosphere of a room, a house, or a locality gives out a permanently disagreeable odour.

128. Some odours, which are at first unpleasant, become by use agreeable. The smell of hartshorn is at first very unpleasant, but by degrees persons take a pleasure in its stimulating effects on the organ of smell, and the habitual use of the smelling bottle is the consequence. In the same way nothing is more unpleasant to a child than a pinch of snuff, but we know by sad experience, that so pleasant does the indulgence of snuff become, that people fill their nostrils with it, and often destroy the power of the olfactory nerves to discern any other kind of odour. These scents and irritating substances, when brought in contact with the nerve of smell in sufficient quantities, produce the spasmodic act called *sneezing*. This is a purely sensori-motor action (83), and is often accompanied with an increased secretion from the membrane of the nose. It is sometimes a good thing to produce sneezing, and is occasionally had recourse to for the purpose of relieving headache.

129. The sense of taste is, in its use, very closely connected with that of smell. In fact, with regard to a large number of things which we introduce into our mouths and place upon the tongue, which we call the organ of taste, they are rather smelt than tasted. Many

EXPLANATION OF PLATE XVIII,

Illustrating the Structure of the Tongue and the Organ of Touch, referred to in paragraphs 98, 113, *and* 129.

Fig. 47 represents the upper surface of the human tongue. On it are seen the papillæ, which are of three forms—1st, *conical*, which are seen at *d*; 2nd, *whip-like*, which are intermixed with the latter and seen at *k* and *i*; 3rd, circumvallate or entrenched, such as are seen at *h* and *l*. These papillæ are the organs of taste. The nerves which proceed to these papillæ are derived from three different sources, and are seen at *e*, *f*, and *g*. Each papilla is comprised of blood-vessels, nerves, and a covering of membrane. *c* is the glottis, and shows the relation of the tongue to the organs of respiration.

Fig. 48 represents the termination of a nerve in a dilated corpuscle. These minute grain-like bodies are called Pacinian corpuscle. They are found in the interior of the papillæ of the skin, more especially those of the fingers. The nerve terminates by penetrating these bodies, and is described as taking a kind of spiral course. The letters *a*, *c*, *d* represent the exterior composition of these bodies, and *b e* the interior.

Fig. 49 illustrates the experiment of crossing two fingers over a single marble. If the eyes are blindfolded this experiment will produce the impression of there being two marbles.

PLATE XVIII

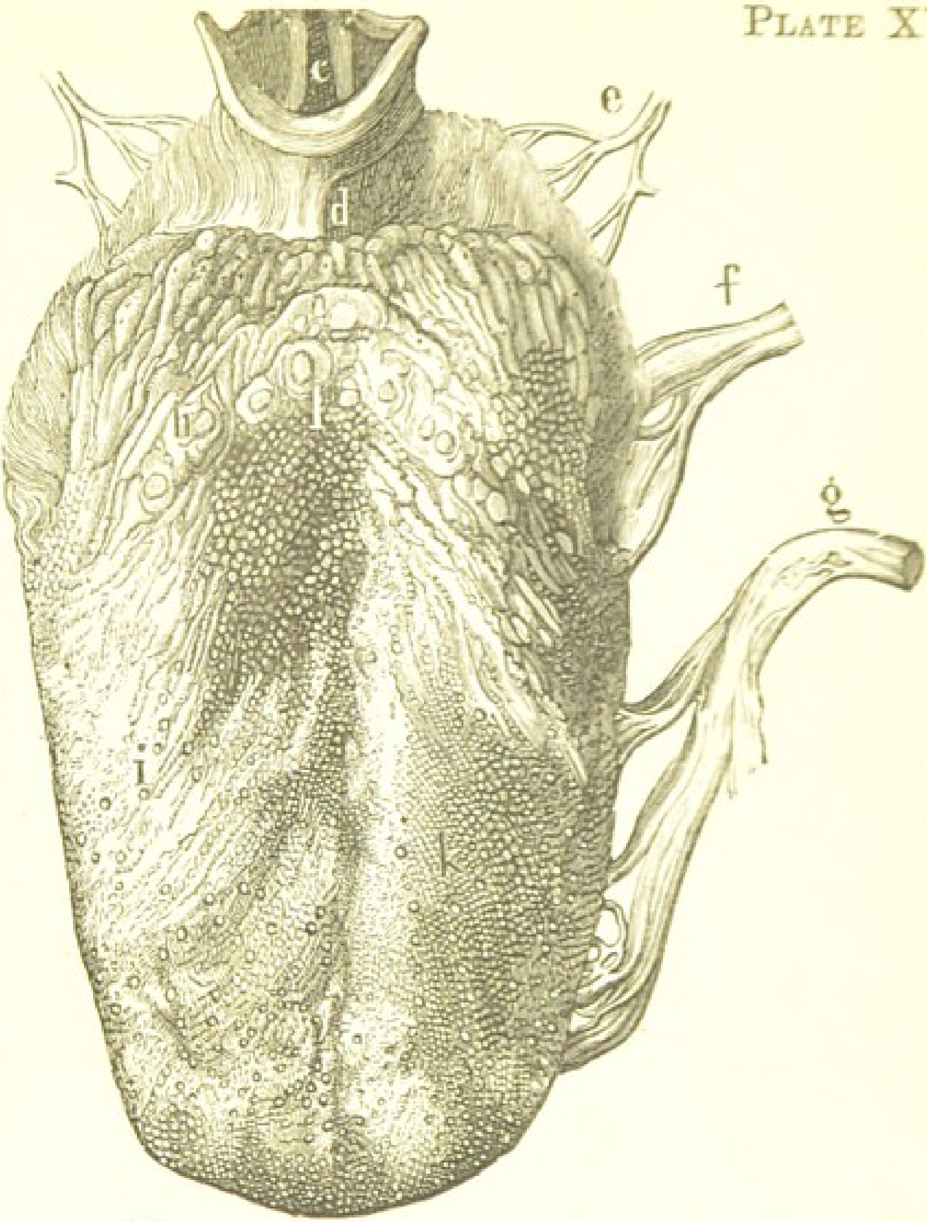


Fig. 47.

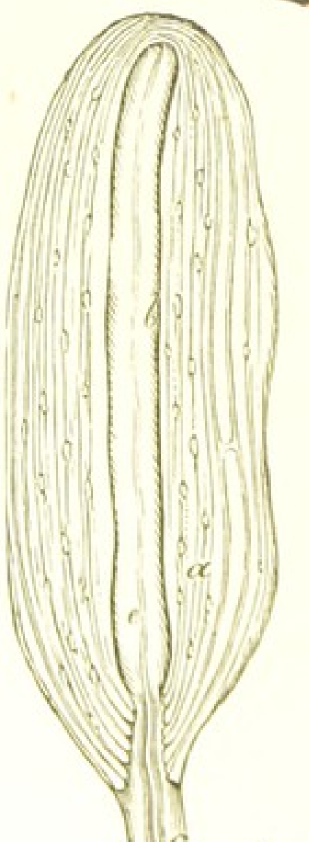


Fig. 48.

Fig. 4

substances which smell before they are put into the mouth, are rather smelt than tasted. This is the case to a great extent with the flavours of tea, coffee, wines, and other beverages, and with food which is flavoured with condiments and spices (22). There are, howev ubstances which we take into our mouths, and ·hose properties are alone appreciated by the tongue. This organ is supplied with a nerve coming off from the base of the brain (a branch of the fifth), called the gustatory nerve. It is distributed by minute branches to the *papillæ* of the tongue. These little organs can be easily observed upon the surface of the tongue, looking like the seeds upon a ripe strawberry. When substances, such as salt or sugar, or alum, are brought in contact with these papillæ, very different and very decided impressions are produced. Such substances address the organ of taste. It will be seen that the pleasure we derive from eating and drinking, is due to the impressions produced on both the nerves of smell and taste, and in fact the nerves of common sensation which are supplied to the nose, mouth, and throat, are brought into play in the gratification we derive from taking food.

130. We have now accomplished the task we proposed in writing this little book. We hope we have said sufficient of the structure of the human body to enable all our readers to understand the operation of the great Laws on which the health and life of human beings depend. It should be recollected that these are God's Laws, and that He will not suffer them to be broken with impunity. It is not God's will that any should suffer pain, and perish prematurely, but man by his ignorance of the structure and actions of

his body, is constantly breaking the laws of health, and wide-spread misery and desolation are the consequence. It is also to be hoped that many who enter on this study with a desire to benefit themselves by acquiring a knowledge of the means by which their own life, and that of those around them, may be made happy and joyful, will be touched with a feeling of admiration at the wisdom and goodness displayed by God in the creation of man. Man is the highest work of the Creator, and He has given him, above all other creatures, a mind capable of understanding the great laws of his existence, of communicating his thoughts by articulate speech and written symbols, and of accumulating, from age to age, that knowledge by which he may become more and more free from the evils which are the consequence of ignorance and self-indulgence.

QUESTIONS FOR EXAMINATION.

CHAPTER I.

ON THE CONSTITUTION OF THE HUMAN BODY.

WHAT are the four elements of which the human body is principally formed?

Which is the only one that is *solid* at the ordinary temperature of the atmosphere?

In what forms is carbon found?

What gas is formed by the combination of carbon and oxygen gas?

How many pounds of carbon does a human body, weighing 154 pounds or 11 stones, and 5 feet 9 inches high, contain?

What does hydrogen and carbon united form?

What are the flames of a coal fire, and gas, due to?

When hydrogen is burning in the air and unites with the oxygen in the atmosphere, what substance does it form?

What is water composed of?

How do hydrogen and carbon keep up the heat of the human body?

How many pounds of hydrogen are there in a body weighing 154 pounds?

How many parts in every hundred are there of oxygen in the atmosphere?

How many pounds of oxygen are there in a human body weighing 154 lbs.?

What is the more active form of oxygen called, which is found in pure atmospheric air?

How many pounds of nitrogen are found in a human body weighing 154 pounds?

How many parts of nitrogen do 100 parts of atmospheric air contain?

What other elements does a human body contain?

What are bones chiefly composed of?

How much phosphorus is there in a body weighing 154 pounds?

How much calcium?

Are the elements found pure in a human body?

What are the principal compounds produced by the mixture of these elements?

How many pounds of *water* does a body weighing 154 pounds contain?

How many pounds of gelatine are there in a human body weighing 154 pounds?

How many pounds of albumen?

How much fibrine?

How many pounds of fat?

What compound is the *most* constant constituent of both plants and animals?

What are cells, and where are they found?

In what parts of the body is gelatine most abundant?

What is glue made from?

How is leather made?

Where is albumen found?

Where is fat most abundant in the body?

Why do animals become fat in summer and thin in winter?

CHAPTER II.

ON THE NATURE OF THE FOOD SUPPLIED TO THE HUMAN BODY.

WHAT does the food of plants consist of?

Name the three great classes into which the food of man may be divided?

How is it that the human body has a higher temperature than that of the surrounding atmosphere?

What is the temperature of the human body?

Explain the different functions of flesh-forming and heat-giving foods?

Where do we find gluten, fibrin, and casein in the human body?

What substances contain the largest quantity of carbon?

What is starch?

What articles of food consist principally of starch?

What is the action of the saliva in the mouth on starch?

By what process is sugar converted into alcohol?

What is the most heat-giving article of food?

Why do doctors give cod-liver oil?

How can we obtain the mineral and saline substances in a human body?

Why is it good to eat uncooked fruit and vegetables?

What is the most important of mineral compounds in the human body?

How much phosphate of lime is found in the bones of the body?

What is the cause of soft and deformed bones?

In what articles of food is phosphate of lime chiefly found?

What is the common name for chloride of sodium?

How much is found in a body weighing 154 pounds?

What is the most efficient cure for scurvy?

Why are fresh vegetables so essential for maintaining health?

What other mineral substances are found in small quantities in the body?

How is the absence of *iron* in the body indicated?

How do condiments, spices, and alcohol act upon the nervous system?

What are the principles contained in tea, coffee, and chocolate?

How much fat does cocoa paste contain?

What are the young of all mammalia fed on for months after birth?

How much milk will a healthy infant of six months old consume daily?

How much food will a man weighing 154 pounds consume daily? (See Table II, p. 134.)

What class of people require most food?

Why is it so essential that people should always drink pure water?

How is water contaminated?

What diseases is contaminated water capable of disseminating?

What was the great outbreak of cholera in 1866 traced to?

How can water be tested as to purity?

How should water always be prepared before drinking?

CHAPTER III.

ON DIGESTION.

What is the function of the teeth?

Describe the different kinds of teeth?

How many teeth ought a grown person to possess?

What is the difference between milk teeth and permanent teeth?

What is the food mixed with during the process of mastication?

What acid is the food mixed with on entering the stomach?

What two fluids is the food subject to on entering the bowels?

What is the effect of these fluids on the food?

How is the food made thoroughly into blood?

How is meat best cooked?

How would you boil a joint of meat?

What would you do with the water the meat had been boiled in?

Why is it better to take warm food than cold?

What is leavened and what is unleavened bread?

What are the meanings of carnivorous, herbivorous, and omnivorous?

How many meals should be taken daily?

Why is it so injurious to take a heavy meal just before going to bed?

CHAPTER IV.

ON THE NATURE OF THE BLOOD AND ITS CIRCULATION BY THE HEART.

Describe the nature and different kinds of blood-globules or blood-cells?

What is the composition of the blood?

What is the nature of glands?

What are the organs by which the blood is carried through the body?

In the mammalia, birds, and man, how is the heart formed?

What are the cavities on each side of the heart in man called?

Describe the course of the blood through the heart?

What is the dark blood and what is the red blood called?

What is the aorta?

What are the blood-vessels carrying the *red* blood called, and what is their structure?

How is the *pulse* produced?

How is the sound of the beating of the heart caused?

How many beats in a minute ought the pulse of a healthy man to give?

What are the capillaries, and the functions they perform?

What diseases are caused by the unhealthy action of the capillaries?

What is the nature and function of the *valves* in the veins?

Describe the structure of the valves of the heart?

What was Harvey's grand discovery?

What is the nature of the blood-vessels in the liver?

CHAPTER V.

ON BREATHING, OR THE FUNCTION OF RESPIRATION.

WHAT great agent is necessary to life in the air we breathe?

How do aquatic animals obtain oxygen?

Describe the process of respiration. What do we take in and what do we give out?

Where is the diaphragm situated, and what is its action?

What are the causes of hiccough, sneezing, yawning, and coughing?

How many times in a minute does the air rush to and from the lungs?

Describe the larynx?

How is the voice produced?

What constitutes the greatest difference between man and the lower animals?

What is the result of taking oxygen into the blood?

At what temperature does water freeze and boil?

What is the temperature of the atmosphere in Great Britain in winter and summer?

What is the *constant* temperature of the body?

Is heat caused by external or internal sources?

How is animal heat produced?

What is the temperature of the blood in ducks and elephants?

What effect has disease upon the temperature of the body?

Why is it so important that the air we breathe should be *pure?*

How much oxygen does one gaslight consume?

Why is it so injurious to sit in crowded rooms, or where much gas is burning?

During the burning of gas and candles what gas is given off?

What diseases are produced by the retention of carbonic acid in the blood?

Why are persons who live in badly ventilated houses much more likely to take infectious diseases than those who obtain a full supply of fresh air?

What sanitary law relating to fresh air has been issued by Government?

What is the nature of ozone?

What mechanical particles are under some circumstances found in the air?

What is the sort of contamination most to be dreaded in the atmosphere?

How many people are killed every year by drain-fever?

What is the great remedy for these contaminations and bad smells?

When deposits of a decomposing nature cannot be got rid of, what should at once be done?

What are the commonest disinfectants sold?

What poisons are given off by *living* bodies?

What is done to prevent smallpox?

How can all infectious diseases be prevented?

What does ventilation mean?

Which is the best way to ventilate a room?

How can you always tell when the air is impure?

Why should a sick-room be always well supplied with fresh air?

How is the poison of all infectious diseases easily destroyed?

What is the meaning of infectious and contagious?

CHAPTER VI.

ON THE STRUCTURE AND FUNCTIONS OF THE SKIN.

What is the temperature of the human body?

Is it changeable according to the climate a person lives in?

What is the source of animal heat?

What is the great agent by which the heat of the body is kept at a given temperature?

How many parts is the human skin composed of?

Where are the black-cells which produce the coloured races found?

What is the nature of the beaks of birds and claws and horns of animals?

Where are the perspiration ducts found?

How many of these little tubes is it calculated are to be found on the surface of a human body?

What is the great function of these sweat tubes?

What are sebaceous follicles and their functions?

What is the result of these follicles getting blocked up with dirt?

What little creature is occasionally to be found in these follicles?

What do we practically learn from these facts?

What is the result of neglecting personal cleanliness?

What should we do to keep the skin in a healthy condition?

What is necessary to enable the skin to perform its functions in relation to the *heat* of the body?

What article of food is most efficient in keeping up the heat of the body?

What is the effect of severe cold upon the systems of old people and young children?

Which are the organs which suffer most from the congestion caused by cold?

Why ought infants and people not able to take active exercise to be most warmly clothed?

What are the chief products used for manufacturing articles of clothing?

What materials are best adapted for keeping the body warm?

Why is it better to wear light-coloured clothing both summer and winter?

Why are light coverings for the head desirable?

Why is it most *injurious* to wear tight clothes?

How can linen and cotton clothes be rendered uninflammable?

What disease is the result of wearing tight garters?

Why are high-heeled boots objectionable?

CHAPTER VII.

ON THE MOVEMENTS OF THE HUMAN BODY.

WHAT creatures possess an internal, and which an external skeleton?

What is the series of central bones called?

What are the higher animals which possess a vertebræ called?

What are those animals which do not possess an internal skeleton called?

Describe the structure of bone and of the teeth?

Name the three principal parts into which the human skeleton is divided?

What are the principal bones of the human body?

What animals have practically four hands?

What feature is most characteristic of the human foot?

What is the difference between voluntary and involuntary muscle?

Describe the muscles and their functions, and the mechanical laws by which they act?

What is required to keep the muscles in health?

Why is exercise necessary?

What exercise is especially adapted for engaging all the muscles?

What are gymnastics?

Describe the effects of exercise upon the system?

CHAPTER VIII.

ON THE BRAIN AND NERVES.

What is one of the most distinguishing features of animals?

What is characteristic of a nerve?

What is the structure and functions of the cilia?

What two structures is the nervous system composed of?

What sort of a nervous system do we find amongst the lower animals?

What is the function of a nervous system?

What are the nerves called which run up *to* the ganglia?

What are those called which run down, conveying impressions *from* the ganglia?

How do the nerves terminate?

What is meant by an excito-motory nervous system?

What are the great masses of nerves collected at the base of the brain?

Describe the structure of the brain?

What are the special functions of the forebrain, midbrain, and hindbrain?

What part of the brain is it that becomes congested under the influence of alcohol?

What is the spinal cord?

How do sympathetic nerves differ from the cerebro-spinal nerves?

How many pairs of nerves come from the brain and branch out on each side?

What are they called, and what are the functions they perform?

How many pairs of nerves does the spinal cord give off?

What are the functions performed by the nerves?

Who are we indebted to for the discovery of the double structure of the roots of the nerves?

What are the minute swellings called which terminate many nerves, and are found in the tips of the fingers and other parts of the body?

What peculiar modification of nervous structure do some fishes possess?

What part of the body is the seat of knowledge and consciousness?

How often does the composition of the human body change?

What is the power that the brain possesses of recalling ideas called?

What is phrenology?

Give the weight of the brains of three celebrated men?

What is the weight of the brain of an idiot and of a chimpanzee?

What is the average weight of the brain of adult males and females?

What function is performed during sleep?

What is the average amount of sleep required by adults?

What class of persons require most sleep?

What is often the result of want of sleep?

What are dreams?

What is the first object of education?

CHAPTER IX.

ON THE ORGANS OF THE SENSES.

How many senses are there, and what are their functions?

What disease is the result of the communication between the nerves and the spinal cord being destroyed?

Describe the structure of the eye?

What is the result of the absence of black pigment in the eye?

What is the function of the iris?

What other defects in structure are the eyes liable to?

For what defects in the eye are spectacles worn?

What is the structure and function of the crystalline lens?

Describe the nature of cataract?

What are the humours of the eye?

What is amaurosis?

What is the function of the lachrymal glands?

What are the best means of educating the eye?

Describe the general structure of the ear in the lower animals and in man?

What organs are contained in the middle and inner ear?

How is sound produced?

What is the function of the tympanum?

What is the nature of music?

How is deafness produced?

Describe the organ of smelling?

What animals possess the function of smelling in the highest degree?

What volatile substances are supposed to possess the power of destroying animal poisons?

Why are disagreeable smells to be avoided?

How is sneezing produced?

Describe the structure of the tongue?

What parts of the tongue receive the impression of taste?

What are the lessons to be learned by the study of the laws of life?

A SERIES OF TABLES

ILLUSTRATING VARIOUS SUBJECTS TREATED OF IN THIS VOLUME.

Table I.

Ultimate Elements of the Human Body.

	lbs.	oz.	gr.
1. *Oxygen*, a gas. The quantity contained in the body occupies a space equal to about 1300 cubic feet ...	111	0	0
2. *Hydrogen*, a gas. The lightest body in nature. The quantity present would occupy about 3000 cubic feet ...	15	0	0
3. *Carbon*, a solid. When obtained from animals it is called animal charcoal...	21	0	0
4. *Nitrogen*, a gas. It would occupy, when free, about 20 cubic feet ...	3	9	0
5. *Phosphorus*, a solid. This substance is so inflammable that it can only be kept in water ...	1	12	190
6. *Calcium*, a solid. The metallic base of lime which has not yet been obtained in sufficient quantity to be employed in the arts. It is about the density of aluminium ...	2	0	0

	lbs.	oz.	gr.
7. *Sulphur*, a solid. A well-known substance. It unites with hydrogen, forming sulphuretted hydrogen, which gives the unpleasant smell to decomposing animal and vegetable matter ...	0	2	219
8. *Fluorine*, a gas. This substance has not been separated in such a manner as to permit of an examination of its properties, and cannot be exhibited. It is found united with calcium in the bones	0	2	0
9. *Chlorine*, a gas. When combined with sodium it forms common salt	0	2	382
10. *Sodium*, a metal. It is so light that it floats on water, and is kept in naphtha to prevent its oxidation	0	2	116
11. *Iron*, a metal in small quantities; it is necessary to the health of the body	0	0	100
12. *Potassium*, a metal. Like sodium it floats on water, and burns with a flame when placed on it	0	0	290
13. *Magnesium*, a metal. Combined with oxygen it forms magnesia	0	0	12
14. *Silicon*, a metallic substance. With oxygen it forms silex or silica. It enters into the composition of the teeth and hair	0	0	2
Total	154	0	0

Other elements have been found in the body, as copper and manganese, but these are probably accidental.

These elements, when combined together, form a set of compound bodies called "proximate principles," out of which the tissues and fluids of the body are formed, as seen in the following table:

Proximate Principles of the Human Body.

	lbs.	oz.	gr.
1. *Water*, composed of oxygen and hydrogen gases	111	0	0
2. *Gelatin*, of which the walls of the cells and many tissues of the body, as the skin and bones, are principally composed	15	0	0
3. *Fat*, which constitutes the adipose tissue	12	0	0
4. *Phosphate of Lime*, forming the principal part of the earthy matter of the bones	5	13	0
5. *Carbonate of Lime*, also entering into the composition of bone	1	0	0
6. *Albumen*, found in the blood and nerves	4	3	0
7. *Fibrin*, forming the muscles and the clot and globules of the blood	4	4	0
8. *Fluoride of Calcium*, found in the bones	0	3	0
9. *Chloride of Sodium*, common salt	0	3	376
10. *Chloride of Potassium*	0	0	10
11. *Sulphate of Soda*	0	1	170
12. *Carbonate of Soda*	0	1	72
13. *Phosphate of Soda*	0	0	400
14. *Sulphate of Potash*	0	0	400
15. *Peroxide of Iron*	0	0	150
16. *Phosphate of Potash*	0	0	100
17. *Phosphate of Magnesia*	0	0	75
18. *Silica*	0	0	3
Total	154	0	0

These compounds in passing away from the body form many others, which may be here left out of consideration as not forming a necessary part of the fabric of the human body.

Table II.

Daily Supply and Waste of the Human Body.

Taken in.		Given out.		
Gases.	ozs.	Gases.	ozs.	grs.
Oxygen . . .	24	*Carbonic Acid* . .	35	0
Liquids.		Carbon 11 ozs.		
Water	93	Oxygen 24 ,,		
In beverages . 68 ozs.		—		
In meat, bread,		35		
and vegetables 25 ,,		Liquids.		
—		*Water* . . .	103	237*
Solids. 93		ozs. grs.		
Flesh-formers . .	4	By Kidneys 51 0		
ozs. grs.		,, Lungs 31 0		
Fibrin 3 0		,, Skin 16 0		
Albumen 0 300		,, Alimentary		
Caseine 0 137		canal 5 237		
4 0		103 237		
Heat-givers . . .	19	Solids.		
Starch . 12 ozs.		Insoluble . . .	2	0
Fats . 5 ,,		Soluble . . .	2	200
Sugar . 2 ,,		ozs. grs.		
—		Urea 1 200		
19		Salts 1 0		
Accessories . .	2	2 200		
Gelatine 1 oz.				
Cellulose 1 ,,				
2				
Mineral Matters .	1			
	143		143	0

* An ounce is 437 grains.

Food subserves two great purposes in the human body. First, it supplies materials for the growth and nourishment of the frame; secondly, it furnishes the fuel which maintains the human body at a temperature of 98°, and gives it force to work.

After the adult age the quantity of elements taken in the food is equivalent to the quantity wasted in the vital actions. The preceding table shows the quantity of substances taken in and given out in twenty-four hours by a person measuring 5 feet 8 inches in height, and weighing 154 pounds.

The quantity of food taken by various individuals differs according to age, height, occupation, climate, season, and state of health.

Age.—Children take more in proportion to their size than adults, as their food supplies the materials of growth as well as waste.

Height.—The height of individuals determines their weight, and according to the quantity of flesh will be the waste and the necessity for supply.

Occupation.—Persons employed in occupations in which great force is exerted and waste of the muscular tissue takes place require more food than those engaged in quiet or sedentary employments.

Climate and Season—Climate makes a great difference in the demand for heat-giving food. Fats, sugar, and starch are eaten in larger quantities in colder climates than in warm. The same holds good of cold and warm seasons.

State of Health.—All forms of disease influence the appetite and the demand of the system for food.

The above table can only be regarded as an approximation to the absolute truth of the case, but it will serve as an illustration of the general law of supply and demand in the human system.

Table III.

Height and Weight.

There is a fixed relationship between the height and weight of healthy individuals. The late Dr. Hutchinson took the height and weight of 2650 healthy men. The results of his observations are given in the following table:

Height in inches or feet.				Calculated, or meanweight.			
Inches		Feet.	In.	lbs.		Stones.	lbs.
61	or	5	1	120	or	8	8
62	,,	5	2	125	,,	8	13
63	,,	5	3	130	,,	9	4
64	,,	5	4	156	,,	9	9
65	,,	5	5	140	,,	10	0
66	,,	5	6	145	,,	10	5
67	,,	5	7	150	,,	10	10
68	,,	5	8	155	,,	11	1
69	,,	5	9	160	,,	11	6
70	,,	5	10	165	,,	11	11
71	,,	5	11	170	,,	12	2
72	,,	6	0	175	,,	12	7

From these observations we may deduce the law that healthy men ought to weigh an additional five pounds for every inch in height beyond sixty-one inches, at which height they ought to weigh 120 pounds. In these cases the weight includes the clothes worn. These should be calculated at $\frac{1}{17}$ the weight, so that a man weighing 170 pounds would weigh only 160 pounds without his clothes.

When persons weigh more or less than the above averages, it generally depends on the presence or absence of fat.

Too large a quantity of fat tends to diminish the vital changes, encumbers the body, increases the work, and enfeebles the action, of the heart, and leads to congestion of the lungs and brain.

Too little fat exposes the body to the action of cold, diminishes the growth of the tissues, and hastens the processes of waste and decay.

Table IV.

Quantity of alcohol, sugar, and acid contained in one imperial pint of various fermented beverages:

	Water.	Alcohol.	Sugar.		Acid.
	ozs.	ozs.	ozs.	grs.	grains.
Table Ale	19½	½	0	251	45
London Porter	19¼	¾	0	267	45
Mild Ale	18¾	1¼	0	280	38
London Stout	18½	1½	0	281	54
Strong Ale	18	2	2	136	54
Pale Ale	17½	2½	0	240	40
Moselle	18¼	1¾	0	0	140
Claret	18	2	0	0	161
Hock	17¾	2¼	0	0	127
Burgundy	17½	2½	0	0	160
Champagne	17	3	1	133	90
Madeira	16	4	0	400	100
Port	16	4	1	2	80
Brown Sherry	15½	4½	0	360	90
Pale Sherry	16	4	0	80	170
Gin (retail)	16	4	½	0	...
Gin (best)	12	8	0	0	...
Whisky	11	9	0	0	...
Brandy	9½	10½	0	80	...
Rum	5	15	0	0	...

The quantity of alcohol drunk by mankind is much larger than is necessary to the maintenance of health.

Children and healthy adults seldom require to take it as a means of securing health or strength.

Small quantities of alcohol in the form of beers and wine amounting to from one to two ounces a day may be taken with impunity.

Persons taking strong exercise in the open air can take more alcohol with impunity than those who live in confined rooms.

Alcohol taken in excess not only produces intoxication, but lays the foundation of the most fatal diseases to which the human body is liable.

Table V.

Showing the Time after Birth at which the teeth ought to appear.

I.—Milk Teeth, Twenty in Number.

	Months.
Central incisors	5— 8
Lateral incisors	7—10
Canine teeth	14—20
First small molars or premolars	12—16
Second small molars or premolars	18—36

II.—Permanent Teeth, Thirty-Two in Number.

	Years.
First true or large molars	6
Central incisors	7
Lateral incisors	8
First premolars	9
Second premolars	10
Canine teeth	11—12
Second true or large molars	12—13
Third true or large molars, also called wisdom teeth	17—19

A CLASSIFICATION OF THE ANIMAL KINGDOM,

WITH EXAMPLES.

SUB-KINGDOM I.—VERTEBRATE ANIMALS. (VERTEBRATA.) Animals with backbones and internal Skeletons.

CLASS I.—MAMMALS (*Mammalia*). Animals, the young of which are born alive, fed by their mothers on milk, breathing by lungs, and having their blood-cells round, with mostly four extremities.

Order I.—TWO-HANDED ANIMALS (*Bimana*). Man.

Order II.—FOUR-HANDED ANIMALS (*Quadrumana*). Apes, baboons, monkeys, and lemurs.

Order III.—FLESHEATERS (*Carnivora*). Lion, wolf, cat, dog, hyena, bear, seal, badger, raccoon.

Order IV.—OPEN-TOED (2 or 4) ANIMALS (*Artio dactyla*). Hippopotamus, pig, camel, cow, sheep.

Order V.—ODD-TOED (1 or 3) ANIMALS (*Perisso dactyla*). Horse, rhinoceros, tapir.

Order VI.—PROBOSCOID ANIMALS (*Proboscidea*). Elephant.

Order VII.—TOXODONTS (*Toxodentia*). An extinct family.

Order VIII.—SIRENS (*Sirenia*). Dugong, Manatee.

Order IX.—CETACEANS (*Cetacea*). Whale, porpoise.

Order X.—WINGED ANIMALS (*Cheiroptera*). Bats.

Order XI.—INSECT-EATERS (*Insectivora*). Hedgehog, shrew, mole.

Order XII.—EDENTATE ANIMALS (*Edentata*). Sloth, armadillo, ant-eater.

Order XIII.—GNAWING ANIMALS (*Rodentia*). Rat, hare, squirrel, beaver, porcupine.

Order XIV.—MARSUPIATE ANIMALS (*Marsupialia*). Kangaroo, wombat, opossum, dasyurus.

Order XV.—MONOTREMES (*Monotremata*). Platypus, echidna.

CLASS II.—BIRDS (*Aves*). Animals covered with feathers, producing their young by eggs, flying by means of their fore extremities, and walking or swinging by their hind extremities, and possessing a double circulation like the mammalia.

Order I.—RAPTORIAL BIRDS (*Raptores*). Eagle, hawk, owl.

Order II.—CLIMBERS (*Scansores*). Parrots, woodpeckers, toucans.

Order III.—PERCHING BIRDS (*Passeres*). Sparrows, blackbirds, thrushes, swallows, linnets.

Order IV.—PIGEONS (*Columbæ*). Pigeon, dove, dodo.

Order V.—POULTRY (*Gallinæ*). Common fowl, pheasant, grouse, peacock.

Order VI.—Running Birds (*Cursores*). Ostrich, green bustard.

Order VII.—Waders (*Grallatores*). Cranes, heron, quail, snipe.

Order VIII.—Web-Footed Birds (*Palmipeds*). Ducks, swan, goose, albatross.

Class III.—Reptiles (*Reptilia*). Animals possessing lungs and breathing air, imperfect hearts, producing young by eggs. This group includes a large number of extinct reptiles, as ichthyosaurus, plesiosaurus, &c.

Order I.—Crocodiles (*Crocodilia*). Alligators, gavials, crocodiles.

Order II.—Lizards (*Lacertilia*). Monitors, iguanas.

Order III.—Serpents (*Ophidia*). Snakes, vipers, blindworms.

Order IV.—Shielded Reptiles (*Chelonia*). Tortoises, turtles.

Class IV.—Amphibious Animals (*Amphibia*). Animals produced from eggs, hatched in water, and leading a part or the whole of their life in water.

This group includes frogs, toads, salamanders, newts.

Class V.—Fishes (*Pisces*). Animals living in water, breathing by means of gills, and mostly covered with scales.

Order I.—Mud Fish (*Dipnoi*). Lepidosyren, rhynocryptis.

Order II.—Placoid Fishes (*Plasmobranchi*). Sharks, rays, chimæra.

Order III.—Ganoid Fishes (*Ganoidei*). Sturgeon, bony pike, fossil fishes as cephalaspis.

Order IV.—Comb-Scaled Fishes (*Ctenordei*). Perch, basse, serranus.

Order V.—Simple-Scaled Fishes (*Cycloidei*). Salmon, whiting, cod, herring.

Order VI.—The Lancelet (*Pharyngobranchii.*)

Sub-Kingdom II.—Invertebrate Animals. (Invertebrata.) Animals with an external skeleton, having no backbone, living in air or water, and breathing by gills, tracheæ, or sacs.

Class I.—Annulose or Ringed Animals (*Annulosa*). The external skeleton is formed of a series of rings, the limbs are jointed, and the nervous system consists of a double series of ganglions.

Order I.—Insects (*Insecta*). Beetles, butterflies, dragonflies, flies, bees, bugs, fleas.

Order II.—Myriapods (*Myriapoda*). Centipedes, millipedes.

Order III.—Spiders (*Arachnida*). Scorpions, mites.

Order IV.—Crustaceans (*Crustacea*). Lobsters, crabs, barnacles, sea acorus, water-fleas, trilobites.

Order V.—Worms (*Annelida*). Land worms, earth worms, leeches.

Order VI.—Worm-like Animals (*Annuloida*). Flukes, tape worms, thread worms, wheel-animalcules, trichina, star-fishes.

CLASS II.—SHELL FISH (*Mollusca*). Animals with soft bodies, mostly included in one or two shells, sometimes naked; nervous system in the form of irregular ganglions.

Order I.—CEPHALOPODS (*Cephalopoda*). Nautilus, argonaut, cuttle fish, ammonites.

Order II.—PTEROPODS (*Pteropoda*). Clio.

Order III.—UNIVALVES OR GASTEROPODS (*Gasteropoda*). Snails, slugs, whelks, periwinkles.

Order IV.—BIVALVES OR LAMELLIBRANCHS (*Lamellibranchiata*). Oyster, cockle, scallop, mussel.

Order V.—BRACHIOPODS (*Brachiopoda*). Lampshell, crania, lingula.

Order VI.—TUNICATES (*Tunicata*). Simple and compound ascidians.

Order VII.—SEA-MATS (*Polyzoa*). Flustra, cellepora, dead-man's fingers.

CLASS III.—RADIATE ANIMALS (*Cœlenterata*). The body ray-like, and stomach an inverted sac without nerves.

Order I.—RAYED ANIMALS (*Actinozoa*). Beroe, cydippe, sea anemorus, coral animals.

Order II.—HYDROZOIDS (*Hydrozoa*). Jelly fishes, lucernaria.

CLASS IV.—FIRST ANIMALS (*Protozoa*). Without stomachs or nerves; simple masses of flesh.

Order I.—RHIZOPODS (*Rhizopoda*). Amœba, actinophrys, foraminifera.

Order II.—SPONGES (*Spongidæ*). Freshwater sponge, common sponge.

Order III.—GREGARINE ANIMALS (*Gregarinidæ*). Gregarinus.

Order IV.—INFUSORY ANIMALCULES (*Infusoria*). Monas, paramœcium.

GLOSSARY.

Alcohol.—The active principle of wine, spirits and beer; it acts upon the nervous system, and produces drunkenness.

Alkalies.—The opposite of acids, which they neutralise.

Animalcules.—Minute animals only seen through a microscope.

Analyse.—To take anything to pieces for the purpose of showing its composition.

Apoplexy.—The sudden deprivation of sense; applied to effusions of blood and water on the brain.

Astringent.—A substance which contracts or draws up any part of the living body to which it may be applied.

Atmosphere.—The air which surrounds the whole globe.

Average.—The sum of several different weights or measures.

Blubber.—The fat of the whale and other animals.

Carbon.—The coal-forming element.

Carnivorous.—That which feeds on the flesh of animals.

Cartilage.—Gristle.

Cavity.—A hole or empty space.

Cell.—A minute bag usually with soft walls and fluid contents.

Circulation.—That which goes round in a circle.

Coagulate.—To thicken; or separate from a solution.

Cocoon.—The case formed by insects before they become perfect.

Collapse.—A falling together, a breaking down, applied to particular organs and a general state of the body.

Compounds.—Two or more elements.

Contagious.—From a Latin word signifying to touch, to come in contact, and applied to diseases caught by contact.

Contamination.—That which renders another substance or thing foul or dirty.

Contraction.—A making smaller.

Converse.—The opposite or other way.

Dietetical.—Relating to food.

Diet.—Food, the food of the day.

DIGESTION.—The process by which the food is prepared in the stomach for being made into blood.

DISINFECTION.—The process of destroying the power of certain poisonous bodies which have the power of producing diseases.

DISSEMINATE.—To spread or scatter around like the sowing of seeds.

DUCTS.—Small fluid tubes.

EFFLUVIUM.—Gases or vapours which pass off from various bodies.

ELEMENTS.—Those bodies in nature which cannot be any further decomposed.

EMACIATED.—Thin, reduced in size.

EQUILIBRIUM.—A body in a fixed or stable state.

EXCRETORY.—That which has the power of throwing off substances from the system.

EXTREMITIES.—The extreme parts, the arms and legs.

FERMENTATION.—The process by which sugar is converted into alcohol.

FIBRES.—Small cords or lines.

FIBRINE.—A compound separating into small fibres.

FOLLICLE.—A small pit or purse.

FULCRUM.—The point or pivot on which a lever rests.

FUNCTIONS.—The actions of a moving body.

FUNDAMENTALLY.—That which lies at the base or root of a matter.

GANGLIA.—Swellings or enlargements ; more particularly applied to swellings of the nervous system.

GLAND.—An organ which draws substances from the blood, which are either taken up again or rejected.

GLOBULE.—A minute globe, such as the red blood-cells.

GYMNASTICS.—Muscular exercises of definite kinds.

HERBIVOROUS.—That which feeds on herbs or vegetables.

HEXAGONAL.—A figure of six sides.

HYBERNATE.—To sleep or lay dormant in winter.

HYDRA.—A small animal surrounded by tentacles, belonging to the Radiate group.

HYDROGEN.—The water-forming element.

INFECTIOUS.—Applied to diseases which are communicated through the air as well as by contact.

INSANITY.—The absence of soundness of mind.

INSOLUBLE.—Not to be dissolved.

INTERMENT.—The act of burying a dead body.

INTERSTICES.—Spaces between woven or netted textures.

LUBRICATING.—That which makes smooth.

MANIPULATION.—The handling anything.

MINERAL.—That which is not a plant or animal.

MITE.—A minute spider-like insect.

MOLLUSCA.—Soft-bodied animals mostly included in shells as the oyster and whelk.

MORTALITY.—Death, the amount of death in a place.

MORTUARY.—A place where dead bodies are deposited; a dead-house.

MUCUS.—The slime on the surface of the inner passages of the body.

MUCOUS.—The name given to the membranes inside the body which are covered with mucus.

NITROGEN.—The nitre-forming element.

NON-METALLIC.—Applied to elements which are not metals.

NUTRITIOUS.—That which encourages the growth of all or any part of the body.

OLFACTORY.—Pertaining to the sense of smell.

OMNIVOROUS.—That which feeds on both animal and vegetable food.

OPTIC.—Of and relating to the eye.

ORGANIC.—Pertaining to objects which have organs, as plants and animals.

OXIDE.—An element combined with oxygen.

OZONE.—A condition of oxygen gas differing from its common state in the atmosphere.

OXYGEN.—The acid-forming element and the great supporter of combustion.

POLYP.—A tentacle or arm such as surrounds the mouth of the sea anemone.

PORE.—A small hole.

PROPAGATE.—To increase or multiply.

RADIATION.—The act of throwing out rays.

RESONANT.—Sounding hollow when struck.

RESPIRATION.—The function of breathing, including the processes of throwing out air and taking in air in the lungs.

SACS.—Little bags.

SALINE.—Containing common salt, or any other kind of chemical salt.

SCROFULA.—A disease attended with swellings of the glands of the body.

SCURVY.—A disease in which the blood easily exudes from the blood-vessels into the surrounding parts.

SEBACEOUS.—Lard-like.

SECRETION.—A substance formed in the glands of the body.

SEDENTARY.—Sitting.

SPASMODIC.—A sudden and violent action of the muscles of the body.

STIMULANT.—A substance which acts by exciting the action of the nerves or blood-vessels.

SUPERFLUOUS.—More than is wanted.

SYRINGE.—A squirt.

SYSTEM.—An arrangement of parts, as the nervous system or vascular system.

TEMPERATURE.—The heat which bodies show by a thermometer.

THERMOMETER.—Instrument for measuring heat. Fahrenheit's thermometer makes freezing water 32° and boiling water 212°. The centigrade used in France makes these two points 0° and 100°.

FAHRENHEIT.—The inventor of the common thermometer.

THORAX.—The Latin name for the chest.

TISSUE.—A web or texture.

UNCTUOUS.—Greasy, like an ointment.

VALVES.—A mechanical arrangement by which fluids are allowed to pass in one direction but not in the other.

VARICOSE.—Swollen, distended; applied to veins.

VENTILATION.—The act of allowing air to pass in and out of a closed chamber or vessel.

VESICULATE.—Formed of cells or vesicles.

VIBRATION.—Wave-like movements.

VOLATILE.—A substance which easily assumes the form of a gas or vapour.

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