Saunders' Question Books No. 1

PHYSIOLOGY

DR. H. A. HARE

SAUNDERS'

QUESTION BOOKS. No. 1.

PHYSIOLOGY.

QUESTIONS AND ANSWERS

ON THE

ESSENTIALS OF PHYSIOLOGY

PREPARED ESPECIALLY FOR

STUDENTS OF MEDICINE.

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WITH ILLUSTRATIONS.

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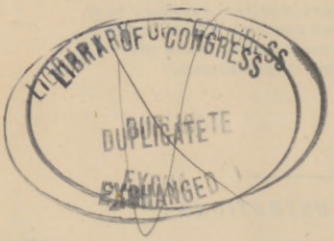

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PREFACE.

At the present time, when the student is forced by the rapid progress of medical science to imbibe an amount of knowledge which is far too great to permit of an attempt on his part to master it, any book which contains the "essentials" of a science in a concise yet readable form must of necessity be of value. The trite saying that "there is no short road to knowledge" is, of course, as true as it is old, and for this reason many of the medical profession have looked with disfavor on books of this character, as being the means by which students might attempt the shorter path.

No one desires more than the writer that the depth and scope of medical education may be increased, but in his belief the evil at present in existence consists in the fact that medical institutions, by granting a degree too early, make the short road to knowledge the only one which the student with the average amount of cerebral gray matter can possibly travel. The evil lies with the small amount of time required for the obtaining of the degree, not with those books which are called into existence by the shortness of the medical curriculum.

The usefulness of arranging the subject in the form of questions and answers will, the writer thinks, be apparent, since the student, in reading the standard works on Physiology, often is at a loss to discover the important points to be remembered, and is equally puzzled when he attempts to formulate ideas as to the manner in which the question could be put in the examination-room.

A manual of this character is in no one way intended to supplant any of the text-books, but to contain, as its title declares, the essence of those physiological facts with which the average student must be familiar.

After considerable thought, it has been considered advisable to exclude points which may be called purely anatomical, and which deprive some of the smaller books on Physiology of the space which might otherwise be occupied by purely physiological statements. The results reached every day by physiological experimenters are many of them so contradictory that no attempt to give individual opinions or teachings has been attempted, the statements made being supposed to represent those facts most generally accepted and taught. The student will, therefore, find statements which are not in accord with those taught by his instructor, and it is for this purpose that the interleaved edition has been published, in order that individual teachings may be noted and remembered. In the compilation of the facts here rehearsed, the standard works of Landois, Yeo, Foster, Dalton, Baker, Hermann, and Chapman have all been consulted.

CONTENTS.

ESSENTIALS OF HUMAN PHYSIOLOGY.

What is physiology?

Physiology is the study of vital phenomena which are always present in living things be they animal or vegetable. As a consequence of this we divide physiology into two subdivisions, known as animal physiology and vegetable physiology, but it should be remembered that the line of demarcation between animals and vegetables in the lower forms of life is very ill-defined. The word physiology is derived from the Greek word *φύσις*, nature, and *λόγος*, a discourse, and in its original meaning was applied to the study of natural history in general. Physiology is really synonymous with the term biology, since it is necessary for the study of either one that vital properties be present in the thing studied. The term biology, however, has a wider scope with certain persons, as under some circumstances it is divided up into morphology, which treats of the forms and structure of living bodies, while physiology attempts to explain the modes of activity exhibited by them during their lifetime. In other words, morphology stands in the same position in reference to physiology as does anatomy. The term *vital phenomena* is applied to the changes which constantly go on in all living bodies, the primary causes of which are not at all understood; in other words, while we note the ultimate object of each function we can give no cause for the setting in motion of that function.

What is the chemical basis of the body?

Of the sixty-three elements known to chemists, a very small number, comparatively speaking, are found in any quantity in living animal matter, although traces of them are frequently present. Oxygen, carbon, hydrogen, and nitrogen are present in very large proportions in every tissue, and together make up about 97 per cent. of the whole body, while the sulphur, phosphorus, chlorine, fluorine, silica, potassium, sodium, magnesium, calcium,

and iron are indispensable to the economy, but are widely distributed and occur in much smaller quantities. Since to investigate the chemical composition of a tissue must require analysis, the composition of the tissues during life is, strictly speaking, unknown, since by the very analysis death is produced. An important point to be remembered is that all animal bodies, be they simple or complex, are made up of protoplasm more or less differentiated according to the function which it is to fulfil.

What two great groups of substances make up the body?

Physiological chemistry teaches us that we have in the body two sets or groups of substances known as *nitrogenous* and *non-nitrogenous*. The nitrogenous perform the most important functions, and, indeed, form all the active portions of the organism. As the simplest representative of these nitrogenous bodies may be mentioned protoplasm itself. Derived from this and entering into the formation of it are albumens, serum-albumens, and, thirdly, by the outcome of still further differentiation we have albuminoids, chiefly represented by gelatine. Last of all are those products which, though nitrogenous, differ from the others in that they are intermediate or effete products of tissue manufacture or waste, as, for example, *urea*, uric acid, kreatin, and kreatinin. The non-nitrogenous substances consist chiefly of the carbohydrates, which contain hydrogen and oxygen in the proportion found in water, as, for example, starch and sugar. Then we have substances containing oxygen in less proportion than the above, namely, fats. Salts occur all through the tissue, as does also water.

PROTEIDS.

All compounds included in the group of proteids contain carbon, hydrogen, nitrogen, oxygen, and sulphur.

They are amorphous, with variable solubility in water and acids, usually soluble in alkalies, almost insoluble in alcohol and ether. They are precipitated from their solutions by excess of strong mineral acids, by acetic or hydrochloric acid, potassium ferrocyanide, and the basic acetate of lead, mercury bichloride, tannin, and potassium carbonate in powder.

The following table, taken from Gamgee's *Physiological Chemistry*, is of great importance, and gives the points to be remembered most tersely. This will be, of necessity, frequently referred to later on.

Soluble in pure water

Class 1.—*Albumens* are proteid bodies which are soluble in water, and which are not precipitated by alkaline carbonates, by sodium chloride, or by very dilute acids. If dried at a temperature below 40° C. they become transparent and yellow, break with vitreous fracture, and are soluble in water. Coagulation occurs between 65° and 73° C.

1. Serum-albumen, not precipitated from its solutions by the addition of ether.
2. Egg-albumen, precipitated from its solution by agitation with ether.

Class 2.—*Peptones*, proteid bodies exceedingly soluble in water. Solutions are not coagulated by heat when precipitated by sodium chloride, nor by acids or alkalies; precipitated by a large excess of absolute alkali and by tannic acid in the presence of much caustic potash or soda. A trace of a solution of copper sulphate produces a beautiful rose color.

Insoluble in pure water, but soluble in weak solutions of common salt

Class 3.—*Globulins*, proteid substances which are insoluble in pure water but soluble in dilute solutions of NaCl. These solutions are coagulated by heat They are soluble in dilute hydrochloric acid, being converted by alkalies into alkali-albumen.

1. Vitellin, not precipitated from its solution when saturated with common salt.
2. Myosin, precipitated from its solution by weak common salt. When saturated with sodium chloride it coagulates at 55° to 60° C. Solutions in common salt are not coagulated by a solution of fibrin-ferment.
3. Fibrinogen, soluble in weak solutions of NaCl, precipitated from them completely on the addition of NaCl when this amounts to twelve or sixteen per cent. Solutions coagulate on the addition of fibrin-ferment and at the temperature of 60° C.
4. Paraglobulin, soluble in weak solutions of NaCl, and precipitated from weak alkaline solutions by the addition of a small quantity of NaCl. A further addition of this body redissolves the precipitate, which is again precipitated, although not so completely as before. When the amount of NaCl in solution exceeds twenty per cent. paraglobulin is completely precipitated when the solution is saturated with ammonium sulphate. Its solutions are not precipitated by the addition of the fibrin ferment It coagulates at different temperatures according to the amount of salts present and the mode of heating, but generally between 68° and 80° C.

CLASS 4.—*Derived albumens*, proteid bodies insoluble in pure water and in solutions of NaCl, but readily soluble in dilute HCl and in dilute alkaline solutions. Solutions are not coagulated by heat.

1. Acid-albumens, obtained by the action of dilute acids, especially HCl, on solutions of proteids, and by action of strong acids upon solid proteids. They occur as first products in the action of gastric juice. NaCl added to saturation precipitates them.
2. (*a*) Alkali-albumens, obtained by the action of dilute alkalies upon the proteids, possessing the properties of acid-albumen with the exception that in the presence of an alkaline phosphate the solutions are not precipitated by neutralization. They occur as the first products of pancreatic digestion.
   (*b*) Casein, the chief proteid constituent of milk, has the same properties as alkali-albumen, but when treated with a strong solution of caustic potash potassium sulphide is formed; with alkali-albumen it is not formed.

CLASS 5.—*Fibrin* is insoluble in water and in weak solutions of NaCl, and becomes swelled up in cold hydrochloric acid of one-tenth per cent. solution, but does not dissolve unless pepsin is added and heat is applied.

1. What test have we for proteids?

The *nitric acid test*, which consists in heating the liquid, and adding nitric acid until the reaction is strongly acid, when a precipitate occurs.

2. What is the xantho-proteic reaction?

Heat with concentrated nitric acid, when, if a proteid be present, a yellow tint appears, which becomes reddish-orange on the addition of alkalies.

3. What is Millon's reagent?

It is made by dissolving in the cold one part of mercury in its weight of concentrated nitric acid, the solution being completed by applying gentle warmth; two volumes of distilled water are then added, and the fluid decanted. This test gives a red color with liquids containing proteids, which is more marked when they are heated to 60° C. or 70° C.

CARBO-HYDRATES.

These include the starches and sugars.

What test have we for starch?

Starch, when added to free iodine, strikes a blue color which disappears on the application of heat, but returns if the liquid be

suddenly cooled. If heated to the temperature of 210° C. starch is converted into dextrin, and, as we shall learn later, the digestive fluids change starch into glucose or grape sugar.

Sugars are substances having a more or less sweet taste, usually soluble in water, destroyed by strong H_2SO_4, which abstracts water from these compounds, and leaves only the carbon. The most important of this group are glucose, lactose, saccharose, and glycogen. On fermentation they yield CO_2 and alcohol.

What test have we for sugars?

Trommer's test, which depends upon the fact that sugar in an alkaline solution acts as a reducing agent. To the saccharine fluid about one-fourth of its bulk of caustic potash or soda is added, and a dilute solution of copper sulphate. A slight clouding occurs which disappears on shaking, but boiling strikes a brick-red color.

Fats are widely distributed in plants and in animals. They contain very little oxygen, and are soluble in ether, benzole, chloroform, and in boiling alcohol. When fats are boiled with solutions of the alkaline hydrates or carbonates they undergo saponification, and are decomposed into glycerin and fatty acids. The latter immediately combine with the alkali and form soap.

THE BLOOD.

What is the function of the blood?

In all animals, except those which form the lowest class, a liquid medium corresponding, in function at least, to the blood of man, circulates. It serves in the distribution of nutritious materials to the various parts of the system and, equally important, it collects those substances which have resulted from the changes which are constantly going on in the tissues and bears them to those organs whose function it is to discharge them from the body. Quite as important is the constant intercourse which it keeps up between the tissues and the air, supplying them with oxygen.

What is the color of the blood in the different portions of the circulatory system?

The color of the blood as it occurs in the arteries is of a bright scarlet-red, while in the veins it is of a dark bluish color.

What is the cause of this variation?

The cause of the variation in these two positions is due to the oxygen of the air, which, entering into a chemical composition with the hæmoglobin of the red blood corpuscles, produces oxyhæmoglobin, which gives up some of its oxygen to the tissues of the body as it passes through the capillaries, and returns in the veins partly decomposed into reduced hæmoglobin, which gives to the venous blood its dark hue.

Is the entire amount of oxyhæmoglobin reduced in venous blood?

No. The reduction of hæmoglobin amounts to only about five per cent.

Are the red blood corpuscles really red?

The blood corpuscles, while they appear red in bulk, are in reality, as is seen when they are spread out in a thin layer on a piece of glass under the microscope, bright yellow; the red hue being chiefly produced by the refraction of light when in large numbers.

What is the reaction of the blood?

The reaction is alkaline, owing to the presence of sodium carbonate and disodic phosphate, Na_2HPO_4.

Does it always retain its alkalinity?

Always during life, but after blood is shed its alkalinity rapidly diminishes, and the greater the alkalinity of the blood is, the more rapidly this change occurs. Finally, the reaction becomes strongly acid, this change coming at about the time of coagulation.

What is the odor of the blood?

The odor which the blood possesses differs in the various animals, and in some animals is very characteristic. This odor depends upon the presence of volatile fatty acids.

What is the taste?

It is saline in taste, which is dependent upon the salts contained in it.

What is the specific gravity of the blood?

The specific gravity is 1055, the extreme limits being from 1045 to 1075. The specific gravity of the blood corpuscles alone is 1105, that of the plasma 1027. As a consequence of this, blood corpuscles tend to sink to the bottom of the beaker.

What is the temperature of the blood?

It varies from 98° F. at the surface of the body to 107° in the hepatic vein.

Of what does the blood consist?

Blood, when flowing in a normal condition through the blood-vessels, consists of an almost colorless fluid, *the plasma*, in which are suspended a number of small solid bodies, known as the red and white blood corpuscles. The liquid portion of the blood, or the blood plasma or liquor sanguinis, is of a pale straw color when free from blood corpuscles or other coloring matter, and is the liquid which keeps the corpuscles afloat. The blood plasma is not identical with the serum of the blood, since radical changes take place in its composition during coagulation, and the serum results after the clot is formed. Serum will not form of itself a clot, plasma will; in other words, one of the differences between liquor sanguinis, or plasma, and serum, is that the first contains the fibrin factors, while the second is without one of them, namely, fibrinogen.

Is there any variation in the character of the blood in different parts of the circulatory system?

The arterial blood contains more oxygen and less CO_2, and is more coagulable. The blood of the portal vein varies with the stages of digestion, during which time it is richer in water, albuminous matters, and sugars, with a diminished number of corpuscles. In the hepatic vein the sugar is increased, but the albumin and fibrin diminished.

What are the two varieties of blood corpuscles?

Red and white.

What others have we?

Very small ones, known as microcytes, and the so-called blood plaque of Bizzozero.

What is the function of these microcytes?

Most physiologists believe them to be young red blood corpuscles, others that they are worn-out red blood corpuscles.

What is the function of the corpuscle of Bizzozero?

It is not known, but they are found in large numbers in thrombi.

Describe the white corpuscles.

They are small protoplasmic cells, differing in no way from the pale round cells found in most portions of the body, and occur in large quantities in the lymph. For this reason they are sometimes called lymphoid cells or leucocytes. They possess a finely granular structure and nuclei, and these nuclei may often be recognized near the centre of the cell. The nuclei may be made more marked by the action of certain reagents, notably acetic acid. They possess an amœboid movement, and so are enabled to migrate not only through the bloodvessel wall, but also through the tissues. They are somewhat larger than the red disks, and do not possess a cell wall.

What do you mean by diapedesis?

The passage of the white blood corpuscles through the bloodvessel wall. The white corpuscles constantly pass through normally, but in very large numbers in inflammation. The red only under morbid conditions, as in injury or inflammation.

What are the relative positions of the red and white corpuscles in the blood stream of the smaller arterioles and capillaries?

The red move along rapidly in the centre, while the white slowly roll along the walls. If inflammation occurs, they stop and block the vessel. The layer of blood in which the white corpuscles lie is called the "still layer."

Where are they formed?

According to the best physiologists, in the lymphatic glands and the spleen, and very similar cells develop in the connective tissues by multiplication by division.

What is their function, and what is their ultimate end?

To form red blood corpuscles. They probably are destroyed in this way.

Describe the red blood corpuscles.

The red blood corpuscles give the red color to the blood of all vertebrated animals except the amphioxus, but are not found in the blood of invertebrates. They differ in their shape in almost all animals, in the mammalia they are biconcave disks. Their size differs in each class of animals, but the size of the animal has no relation to the size of the corpuscle, for in the frog all the corpuscular elements are of great size. They are soft and elastic, and bend and alter their shape when necessary to pass through a narrow bloodvessel, but return immediately to their normal shape as soon as the pressure is removed. If blood be withdrawn from the body, even for a few moments, and then returned to the circulation, death of the corpuscles takes place, and in a short time evidences of their destruction may be noticed by the presence of hæmoglobin in the urine.

What is one of the peculiarities of the red blood corpuscles outside the body?

They form themselves into rouleaux, which resemble very closely the appearance of a large number of coins placed side by side. This peculiarity is rather due to a physical law than to any action of the corpuscles themselves, since it has been found that small disks of cork will do very much the same thing when placed in water.

Have the red blood corpuscles any nuclei?

No, but owing to their biconcave shape the refraction is such that under the microscope a dark spot is apparently situated near their centre.

Are the red blood corpuscles few, or are they exceedingly great in number?

Their quantity is enormous; a cubic millimetre contains between four and five millions. Approximate mathematical estimates show that the red blood corpuscles of an adult present an aggregate surface of about three thousand square yards, while the surface they represent for the absorption of oxygen in the lungs in one second is about eighty square yards.

How are they formed?

The red blood corpuscles are probably derived from the spleen, liver, and red medulla of bones, where they are found in transitional states, and are probably the offspring of the white corpuscles to a certain extent.

What is the end of the life history of the red blood corpuscles?

Most physiologists regard the liver as one of the chief places where the disintegration of the red blood corpuscles takes place, and this is supported by the facts that the bile-pigments are formed from hæmoglobin and that the blood of the hepatic vein contains fewer red blood corpuscles than the blood of the portal vein. The spleen is also regarded as one of the organs in which the red blood corpuscle is disintegrated.

What are the functions of the red corpuscles, and their relative number to the white corpuscles?

The function of the red blood corpuscles is entirely different from that of the white blood corpuscles. The red blood corpuscle contains in its stroma a large amount of hæmoglobin which, when exposed to the air in the lung, takes up oxygen, thereby forming the chemical compound known as oxy-hæmoglobin. By these means the tissues, even in the most distantly removed parts of the body from the lung, receive their oxygen, the exchange of oxygen from the corpuscles to the tissues taking place in the capillaries. By this means, oxidation, with the resulting tissue break-down, and the development of heat, takes place in every portion of the body.

The relative number of the red blood corpuscles to the white has been much discussed, some observers insisting that it is one to fifty, while the majority insist that it is more frequently one to four hundred.

Do changes ever occur in the relative number of red and white corpuscles in health?

Very frequently; since many circumstances arising in every-day life may produce great changes in this respect. The variation may go all the way from one in fifty to one to twelve hundred. Pregnancy decreases the proportion; meals also have a very powerful effect on their relative numbers. Certain diseases also alter the proportion greatly.

What is hæmoglobin?

It is the substance which gives the red color to the corpuscles, and carries by their aid the oxygen to the tissues.

What is hæmatin?

A result of the decomposition of hæmoglobin. Hæmatin is synonymous with hæmin, while hæmatoidin occurs only when blood coagulates outside the circulation, or becomes decomposed, as in extravasations into the tissues. A third substance derived from hæmoglobin is known as the colorless proteid of hæmoglobin.

What are the gases of the blood?

Chiefly oxygen, carbonic acid, and nitrogen. The oxygen exists, as before stated, in chemical combination with the hæmoglobin, and also in small amounts is simply absorbed in the blood plasma.

Carbonic acid occurs in small amount in arterial blood, in much larger amount in venous blood.

Nitrogen exists in the blood in very small amounts, and appears to be simply absorbed.

Does CO_2 unite with the hæmoglobin?

No. It is held in solution chiefly by the plasma, and in very small amounts in the red blood corpuscles.

What is the quantity of the blood?

The quantity of the blood is equal to one-thirteenth part of the body weight.

COAGULATION OF BLOOD.

Blood, on being withdrawn from a vessel, is perfectly fluid, but rapidly becomes thick, and then forms a clot resembling a solid gelatinous mass.

What is this clotting due to?

The presence of fibrin.

What is fibrin?

Fibrin is that substance which, becoming solid in shed blood, or in lymph, causes coagulation.

Does fibrin exist already formed in the blood?

No.

How is it produced?

It is produced by the coming together of two proteid substances which occur dissolved in the plasma, namely, *fibrinogen* and *fibrinoplastin*, or *paraglobulin*, and a ferment necessarily present, known as the *fibrin-ferment*.

What is the difference between fibrinogen and fibrinoplastin?

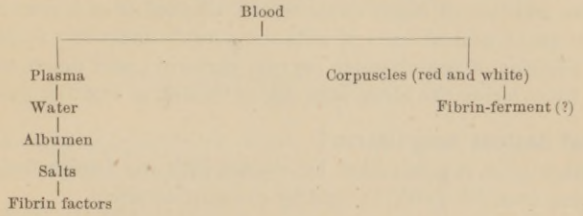
The difference is not well marked. Fibrinogen is found in serous exudations, as in the pericardium and peritoneum, in pleural cavities, and in hydrocele. In these fluids no fibrinoplastin exists. Fibrinoplastin may be readily prepared from blood serum, in which, however, there is no fibrinogen.

The liquid of serous effusions will not coagulate, neither will blood serum, occurring after clotting, clot of itself; but if one fluid be added to the other coagulation occurs. One liquid contains one fibrin factor, the other, the other.

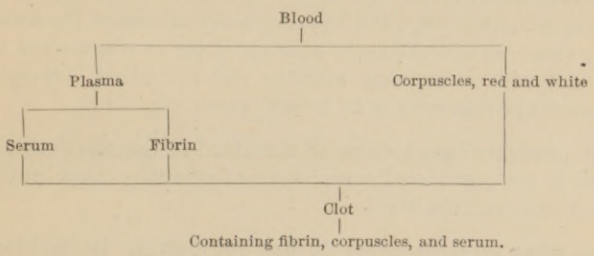
How is the clot made up?

The fibrin forms in fibrils, which entangle the blood corpuscles, as in a spider's web, and thereby form a complete blood-clot.

The blood in the body is made up as follows:



Blood when it has undergone coagulation is as follows:



What changes take place after the clot is formed?

The clot leaves the sides of the vessel, and on its surface there appear small transparent drops of yellowish liquid known as serum. These drops running together form a layer of yellowish fluid.

In what way is the serum expelled from the clot?

The fine fibrils of fibrin ramifying all through the clot contract, and squeeze out the serum. These fibrils also entangle the corpuscles.

How long does this contraction and displacement of the serum last?

From twenty-four to thirty-six hours.

How do you defibrinate blood?

By beating it with twigs or a glass rod. The fibrin adheres in sticky masses to the rods, and the remaining fluid will not clot. The corpuscles are left, most of them in the serum.

What conditions hinder or delay coagulation?

The addition of small quantities of alkalies or of concentrated solutions of neutral salts of alkalies, notably magnesic sulphate; the addition of egg-albumen, syrup, glycerine, and much water; and by covering the blood with oil, or by cold at freezing point.

What hastens coagulation?

Coagulation is accelerated by contact with any foreign body, by heating from 39° to 55° C., and by constant agitation.

What do you mean by the buffy coat?

In blood which is drawn from a body during inflammation the fibrin coagulates slowly, and the corpuscles subside to the bottom of the vessel, so that the upper stratum of the clot is not red but only yellowish, containing scarcely any red blood corpuscles. This occurs physiologically in horses' blood.

What prevents coagulation of the blood in the bloodvessels?

This is not positively known; some relationship exists between living tissues and the blood.

Under what circumstances do you get clotting in the bloodvessels?

As soon as the endothelial layer of the bloodvessels is in any way injured.

How long after death does the blood coagulate in the body?

From ten to twenty-four hours.

Do pathological changes ever take place in the blood?

Yes. *Plethora* is an increase in the quantity and quality of the blood, the red corpuscular elements being greatly increased in number

Anæmia is a decrease in the corpuscular elements of the blood, without necessarily any increase in the liquids.

Leucocythemia is a term applied to a condition in which the white blood corpuscles are in greater proportion to the red than normal, the proportion often being one to one to twenty-five or thirty.

Uræmia cannot be considered a disease of the blood, but simply an accumulation of urea in that fluid, owing to kidney disorders.

THE HEART.

What is the function of the heart?

To propel blood through the body.

How many cavities has it?

Four.

What is the difference between the right and left side of the heart?

The right side of the heart takes the venous blood from the vena cavæ and pumps it through the lungs to the left side of the heart. This circulation is much more limited, of course, than that produced by the left side, and is known as the *pulmonic circulation.* The left side of the heart receives the arterialized blood from the lung and drives it into the general arteries. This is known as the *systemic circulation.*

Which is the strongest, the right or left side of the heart?

The left side is not only much stronger, but its walls are much thicker on account of the greater amount of work which it is forced to perform.

What is the difference between the contraction of the auricles and the contraction of the ventricles?

The contraction of the ventricles takes place synchronously from all sides, so that the pressure within is equal in any direction. The auricles contract peristaltically from the opening of the supplying vessel toward the auriculo-ventricular orifice.

Which have the thickest walls, the ventricles or the auricles?

The ventricles, owing to the greater force which they are required to put out.

What is the function of the auricle?

To force the blood through the auriculo-ventricular opening and so supply the ventricles.

Has the heart any suction power enabling it to aid the circulation, not only by pushing but by sucking?

According to the latest researches it has not.[1]

What are the valves of the heart?

They are fibrous flaps arranged in one of two ways, which open and shut the orifices which they guard. The edges of the auriculo-ventricular valves are attached by what are known as chordæ tendineæ to the walls of the ventricles.

What is the function of the valves?

To prevent the regurgitation of blood from a heart cavity, or bloodvessel, back into the area from which it has been propelled.

What two sets of valves have we?

The auriculo-ventricular and semilunar.

Where are they situated?

The semilunars guard the opening of the aorta and pulmonary artery.

At the right auriculo-ventricular orifice we have the tricuspid valve, at the left auriculo-ventricular we have the mitral or bicuspid valve.

How many cusps make up the semilunars?

Three at each opening.

Are there any valves at the opening of the cavæ into the right auricle?

No.

Why are they not needed?

Because the peristaltic action of the auricle prevents a tendency

[1] The muscular arrangement of the heart is probably already known to the student; if not, he must turn to his anatomical text-books.

to regurgitation, except in rare conditions. For the same reason we have no valve at the opening of the pulmonary vein into the left auricle.

What are the chordæ tendineæ ?

The chordæ tendineæ are small bands running from the muscular fibres of the heart wall to the edges of the valves.

What is the function of the chordæ tendineæ ?

To prevent the everting of the auriculo-ventricular valves into the auricles by a sudden pressure of blood during ventricular systole.

What are the columnæ carneæ ?

They are small ridges of muscular tissue lying on the ventricular wall.

What are the musculi papillares ?

They are small teat-like muscular projections arising from the inner portion of the ventricular wall, to which the chordæ tendineæ are generally attached.

What is their function ?

As the ventricle contracts they pull the chordæ tendineæ tense.

In what way does the blood circulate through the heart ?

Entering the right auricle from the cavæ, it passes from the right auriculo-ventricular opening into the right ventricle, then through the pulmonary artery into the lungs, from the lungs through the pulmonary veins to the left auricle, and through the left auriculo-ventricular orifice to the left ventr cle, from the ventricle through the aorta, and so on through t e arterial system.

How much blood is sent out of the left ventricle ordinarily in the adult at one contraction ?

About four to six ounces.

How much force does the heart put out at each systole ?

Enough to lift three foot-pounds.[1] Of this the left ventricle

[1] A foot-pound represents the force required to lift one pound one foot.

does two and a quarter pounds. In twenty-four hours the heart puts out enough force to lift one hundred and twenty-four foot-*tons*, or enough to lift one ton one hundred and twenty-four feet.

What are the movements of the heart?

The chief movements are those of contraction, or systole, and expansion, or diastole.

The two auricles contract synchronously, thereby filling the ventricles, then the ventricles contract together, and then follows diastole. Following ventricular diastole there is a *pause*.

Systole, diastole, and the pause, therefore, make up one cardiac revolution.

Does the heart change its position during contraction or expansion?

Yes, somewhat; for, with contraction, the base of the heart descends, the base of the ventricle goes toward the left but the whole heart rotates a little to the right, and the apex is tilted a little forward. The vertical movement of the apex amounts to nothing.

At what time does the impulse of the heart take place against the chest?

During systole.

When the heart is slowed or quickened, is the change in speed due to a change in systole or diastole, or both?

Systole remains unaltered, diastole is prolonged when slowing occurs, shortened when quickening occurs.

How many heart sounds have we?

Two; the long, dull "lub," and the short, sharp "dup."

What are the sounds of the heart due to?

The first sound is due to the vibration of the auriculo-ventricular valves made tense by the systolic force of the ventricles, and also the sudden contraction of the muscular fibres of the heart walls. The striking of the apex against the chest wall does *not* even help the first sound, since it can be heard after the wall is

removed. The second sound is produced by the closure of the aortic valves.

At what rate does the heart beat?

Before birth, per minute, the beats are 140–150.
During first year, per minute, the beats are 125–135.
During third year, per minute, the beats are 95–100.
During eighth, ninth, and tenth to fourteenth year, 85–90.
In the adult, about 72.
In very old age, or decrepitude, the pulse once more becomes fast.

In which sex is the pulse most rapid?

In females.

What effect has posture on the pulse?

The erect posture causes a more rapid pulse than when lying down.

What other conditions influence its rate?

Respiratory changes, drinking water in small repeated swallows, and many similar conditions.

What is the intrinsic nervous mechanism of the heart?

The intrinsic nervous mechanism of the heart consists in three centres, which have been proved to exist in the heart of the frog, and are generally received as the centres for the mammalian heart. The three centres are:

1. The motor ganglion, or that of Remak.
2. The accelerator, or second motor ganglion, or that of Bidder.
3. The inhibitory ganglion, or that of Ludwig.

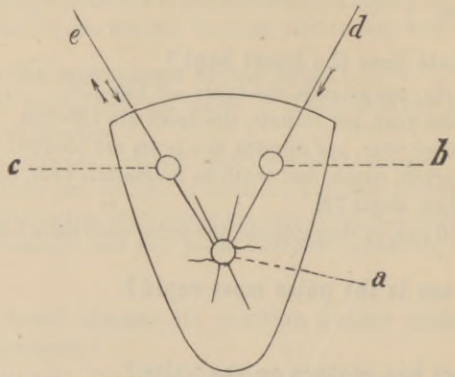
Fig. 1. will serve to illustrate the matter:

The motor ganglion (*a*) sends out through its radiating fibres impulses which drive the heart.

The accelerator motor ganglion (*b*), when it acts, quickens the irradiation of these impulses.

The inhibitory ganglion (*c*) prevents the heart from beating too fast.

FIG. 1.



a. The motor centre, that of Remak. *b*. The accelerator motor centre, that of Bidder. *c*. The inhibitory centre, that of Ludwig. *d*. The accelerator nerves. *e*. The pneumogastric or inhibitory nerves. The arrows represent direction in which impulses travel.

What keeps up the contraction of the muscle?

The constant circulation of the blood over the endothelium, thereby stimulating and sending reflex impulses to the motor ganglion.

What are the extrinsic cardiac nerves?

The accelerators and the pneumogastric or inhibitory nerves, which arise in the base of the brain and are governed by centres there.

What is their function?

They govern the ganglia in the heart muscle.

Are the pneumogastric nerves and the accelerators, strictly speaking, antagonists?

They are not, for the accelerators do not act all the time, while the pneumogastrics do, and the vagi can always overcome readily any accelerator influence.

What effect on the heart has stimulation of the pneumogastrics

It slows the pulse and produces large and full diastole.

What effect has section of the vagus?

It produces an exceedingly rapid pulse.

What effect has stimulation of the accelerators?

Stimulation of the accelerators makes a very rapid pulse.

What is the depressor nerve, and what is its function?

The depressor nerve is given off from the superior laryngeal nerve and the trunk of the vagus in the rabbit, and passes into the cardiac plexus It conducts impulses from the heart to the vasomotor centre, and lowers the activity of that centre, thereby relaxing the bloodvessels somewhat. In this way the heart when overworked, owing to the increased resistance of high blood pressure (vasomotor spasm), can be relieved as soon as is necessary.

What is the function of the so-called pressor fibres of the laryngeal nerves?

They stimulate the vasomotor centre, causing a rise of blood pressure. They are, therefore, the direct opponents of the depressor fibres.

What are the functions of the bloodvessels?

The bloodvessels carry blood to and from the various tissues and organs. They are divided up into three divisions, known as: 1, arteries and arterioles; 2, capillaries; 3, veins. Of these three, the capillaries are most important in their function, since they not only carry blood, but, owing to the peculiarity of their walls, bring the blood into intimate relation with the tissues. The fluid which escapes from the capillaries is known as lymph, and the function of lymph is to irrigate and nourish.

What is the difference between arteries, veins, and capillaries?

Arteries differ from veins in having thicker walls, owing to a greater development of their outer coats.

Remember! The fact that arteries do not contain valves is not a differential point, since some veins contain no valves.

How many coats have the arteries?

They contain three coats, known as the *outer*, or *tunica adventitia;*

the *middle*, or *tunica media;* the *inner*, or *tunica intima*. The last of these is made up of transparent *endothelium*, composed of irregular, long, fusiform cells held together by a cement substance which is stained black by nitrate of silver ($AgNO_3$). Outside the endothelial coat lies a very thin, more or less fibrous layer, the *sub-endothelial;* and outside of this is the *elastic lamina*, which in the smallest arteries amounts to nothing more than a structureless or fibrous membrane, whilst in the other vessels its function is most important. It is known as the *fenestrated membrane*. The *tunica media* contains much unstriped muscular fibre, which increases in amount as the vessel grows larger. Most of these fibres are circular, completely surrounding the vessel, while a much smaller number run longitudinally. The *tunica adventitia*, or the outer coat in the smallest arteries, is a structureless membrane which changes into a fibrous membrane as the vessel increases in size.

What are the functions of these coats?

The *endothelial layer* forms a smooth surface over which the blood may pass, and the importance of this will be understood when it is remembered that rough surfaces aid in the coagulation of the blood. The *muscular coat* regulates the amount of blood received by each part and governs the *elastic coat*. This is necessary, since it is manifest that the heart cannot regulate the blood supply of each portion of the body.

Does the muscular coat aid in the propulsion of the blood?

No; it must be distinctly remembered that in the higher animals, *particularly in man*, the muscular coat probably aids very slightly in the propulsion of blood.

In what way do these coats aid in arresting hemorrhage?

The muscular coat aids, in conjunction with the elastic coat, in the prevention of extensive hemorrhage by contracting the opening in the bloodvessel, turning in its edges so that the opening is greatly decreased in calibre.

What other function has the elastic coat?

A more important function of the elastic coat is the prevention of sudden pressure in any portion of the body by yielding partially to a sudden strain or controlling a tendency to too great a dilatation. It, therefore, equalizes blood pressure during diastole and systole, and were it not for this important coat the arteries would be entirely emptied during diastole and filled to bursting during systole.

What is the function of the outer fibrous coat of the larger bloodvessels?

To protect the bloodvessels from injuries from the exterior and to give the bloodvessel walls support. If it were not for the fibrous coat a ligature applied to a vessel would cut through.

What have we in the veins which do not occur in arteries?

Valves which flap back against the wall of the vessel as the blood flows onward, but which prevent any reflux should the current be reversed by any cause.

How are these valves arranged, singly or in pairs?

In pairs.

Is there any difference in the capacity of the various portions of the vascular system?

The combined calibre of the branches of an artery exceed in their capacity that of the parent trunk, and so soon as the muscular coat of an artery is past the capacity of the vascular system is enormously increased. The capillaries are capable of holding eight hundred times as much blood as the aorta. The veins diminish in area as they come toward the heart, whilst the arteries increase as they go toward the periphery. The capacity of a vein is always greater than that of a corresponding artery; even at the heart the capacity of the venæ cavæ is twice as great as that of the aorta.

What do you mean by blood pressure?

The pressure under which the blood stream is kept by the action of the heart and the walls of the bloodvessels.

Is the blood pressure always constant in man and animals?

The blood pressure varies from many causes, and differs in nearly all animals. In the rabbit it can support a column of mercury from two to three and a half inches in height, in the dog from four to five and a half inches, in the horse from eight to twelve inches, while in man the pressure will hold a column of mercury as high as five and three-fourths inches. The pressure in the human aorta is estimated at four pounds and four ounces, in the horse eleven pounds and nine ounces, in the radial artery of man at four drachms, in the pulmonary artery two pounds and two ounces. But it must be remembered that these figures represent the maximum amounts at the moment of ventricular systole. The pressure is least in the capillaries, greatest in the aorta. The venous pressure is only one-tenth that of the arterial pressure.

What is the influence of the nervous system on blood pressure?

Nerves supply all the arteries and arterioles, and even the capillaries and veins, and belong to the so-called sympathetic system.

What are these nerves called?

Vaso-motor nerves.

How are they arranged and governed?

By a centre in the medulla oblongata known as the *vaso-motor centre*, which is situated near the calamus scriptorius and the corpora quadrigemina, the tension of the vascular system is governed. Fibres from this centre pass down in the neck through the spinal cord, and find exit with the anterior roots of the spinal nerves. The vaso-motor centre is probably always at work, and to aid it we have scattered through the spinal cord, and in various portions of the body, lesser centres under its control, but capable of originating impulses themselves.

What proof have we that this is so?

If the cervical sympathetic be cut on one side in the rabbit, or in any animal, that side of the head becomes very rapidly deeply suffused and congested, and remains in this condition for many hours. Finally, however, the color returns almost to normal, and

congestion goes down. The first dilatation was due to the fact that the governing centre in the medulla by the section, was cut off from that side, and the minor centre not being accustomed to send out powerful impulses, is unable to govern its tributary bloodvessels. In a short time, however, the local centre gathers power, and once more exerts not only its previous influence over the vascular supply of that side, but also is enabled to supplement the action of the higher centre in the medulla, which, before the section, constantly aided it in its efforts.

What effect has stimulation of the vaso-motor system on blood pressure?

It raises it by contraction of the bloodvessels all over the body.

What effect has depression of the vaso-motor system on blood pressure?

It lowers it by dilatation of the bloodvessels.

What effect has division of a vaso-motor nerve on its tributary vessels?

It produces palsy, or relaxation, of its tributary muscles in the wall of the bloodvessel, and, as a consequence, a local or, if the vessels are large enough, indirectly a general fall in blood pressure, by drawing a large amount of blood from the general system. Stimulation of a nerve, on the other hand, produces a contraction of these muscles and a rise of pressure. Blushing is a good example of vaso-motor disturbance of the nervous apparatus governing the vascular system.

What effect has galvanization of a sensory nerve on general blood pressure?

It raises it.

What effect has it on bloodvessels of a leg in which the sensory nerve is galvanized?

It dilates them and locally lowers pressure.

What effect has asphyxia on blood pressure?

It increases it by stimulation of the vaso-motor centre in the medulla by the increased amount of CO_2 in the blood.

What effect has section of the spinal cord on blood pressure?

It produces a great fall in pressure, due to the cutting off of the vaso-motor centre in the medulla from the vascular system all through the body.

What effect has paralysis of the vaso-motor nerves supplying the abdominal bloodvessels?

A general fall in blood pressure all over the body.

Why is this so?

Because these bloodvessels are capable of holding all the blood in the body, and so starve the rest of the vascular system.

What other causes increase arterial pressure?

Increased heart action, whereby more blood is driven out into the bloodvessels in a given space of time. The increase in heart action may be by increased rate or force, the result is the same.

What are the physical forces of the circulation?

Liquid always goes away from pressure, and the pressure depends on the ease of escape and the forces from behind. If a tube be elastic, and its distal end open and small, it will be found that though the liquid enters it in jerks at the proximal end, it will leave the distal end in a steady stream, but if the tube is rigid the liquid moves in jerks along its whole length. This is the *key* to the circulation.

Under what conditions is the blood placed after being driven out of the ventricle into the arterial system?

Just before the arteries are changed into capillaries they are known as arterioles; it is in these arterioles that we still have the muscular coat quite powerfully developed and governed by the vaso-motor system. These muscular coats are kept at a certain degree of tonicity, producing thereby a considerable narrowing of the blood paths, and they, therefore, prevent the blood from flowing out into the capillary system too rapidly. On the other hand, the force given to the blood by the heart has so distended

the arterial system, particularly in the larger trunks, that the elastic coats have been greatly stretched, and no sooner does the pressure from the heart muscle cease than they contract on the blood. Pressed upon in this manner on all sides, the blood endeavors to find some mode of exit, and is prevented from regurgitating back into the ventricle, in health, by the valves at the aortic opening. As a consequence, the blood obeys the physical law already mentioned, and passes in the direction of least resistance, namely, through the contracted arterioles.

What is the function, therefore, of the arterioles?

To prevent too rapid a flow into the capillary system, which, if permitted, would immediately starve both the arteries and veins of their proper amount of blood, since, as before noted, the capacity of the capillaries is extremely great.

What aids blood flow in the capillaries?

Capillary attraction and pressure due to muscular movements of the body. Also to the action of the heart and arterial coats.

What aids blood flow in the veins?

Lateral pressure exerted by contraction of the voluntary muscles of the body, the indirect action of the valves in the veins, and, to a slight degree, the heart force. Also, the suction produced by movements of the thorax in respiration (not the heart).

Does the blood find it more difficult to return through the veins than to descend through the arteries?

No; the circulation in this respect resembles a U-shaped tube filled with mercury, in which the column rises on one side, due to pressure or displacement on the other. In othe words, the blood descending in the femoral artery shoves the blood up the corresponding vein.

Is there difference in the rapidity of the flow of the blood in the arteries, capillaries, and veins?

Yes; in the artery the flow is very rapid and in spurts, in the capillaries it is many times slower and generally moves in a steady

stream. In the veins the rapidity of the flow increases as the blood nears the heart, but moves in a steady stream, and does not attain the speed of the blood in the arteries.

What is the pulse?

The pulse is caused by a wave of force which travels along the column of blood in an artery as a direct result of a single contraction of the heart; in other words, each pulse represents a heart beat, but not the blood thrown out at that beat. The stroke given by the heart in propelling the blood onward is expended in causing not only the forward movement of the whole mass of blood, but also the latter expansion already spoken of. As a consequence of this, each pulse is like an expansion wave, causing the vessel to expand by reason of the increased tension and force produced by the heart from behind.

Is the rapidity of the pulse wave the same as the rapidity of the blood stream in the artery?

No; the main current passes along the vessel at a given rate of speed, while the force of each systole is transmitted along the blood stream as if it were a solid piece of metal or wood, which, having been struck at one end, transmits a wave of force to the other end. The blood being enclosed in partially rigid walls carries the impulse chiefly forward, not laterally. The pulse wave is twenty or thirty times as rapid as the blood current itself.

Does the pulse cause simply a lateral dilatation of the bloodvessel?

No; the bloodvessel is not only widened, but lengthened, so that a straight artery may be seen not only to dilate, but also to become curved to make up for its elongation.

Is the pulse wave equally strong in all portions of the body?

No; it diminishes in force and in speed as it travels onward, due to the force expended in distending successive parts of the bloodvessel, friction, and other causes. As a consequence of this, the pulse in certain portions of the body occurs an appreciable length of time after the cardiac contraction which has produced it. This

is noticed particularly in the radial artery, or markedly in the dorsalis pedis artery. The delay, however, even at the most distant point amounts to not more than one-sixth to one-eighth of a second.

At what speed does the blood circulate?

About ten metres or thirty-five feet per second, and takes but one-third of a second to pass a given point. The length of each pulse wave is, therefore, about three metres (9½ feet), or twice the length of the longest artery. When the last part of the pulse wave has passed the arch of the aorta the first part has just reached the arterioles.

RESPIRATION.

The respiratory apparatus is divided into the larynx, trachea, bronchial tubes, bronchioles, and vesicles in the lung. Surrounding each lung are the pleuræ, one layer of which is attached to the lung (visceral layer), the other to the chest wall (parietal layer).

What is the object of respiration?

In order to bring the oxygen of the air in close relationship with the hæmoglobin in the blood, and to permit of the elimination of CO_2 from the body, as well as other effete products in very minute amount. The enlargement of the chest occurs with *inspiration*, the contraction of the chest with *expiration*.

How many varieties of blood-supply exist in the lung?

Two; the *pulmonary artery* supply, and the *bronchial artery* supply.

What is the function of these two varieties?

The pulmonary artery supplies the blood for aëration, the bronchial artery that for the nourishment of the lung-tissue itself.

In what manner is the blood brought to the vesicles and exposed to the air?

The smaller branches of the pulmonary artery split up more and more, and have the *peculiarity that they do not anastomose* with one another. The fine capillaries run between the air vesicles, the

thin wall of the vessel and vesicle permitting the free interchange of gases to take place.

What difference do we have in the distribution of the bronchial and pulmonary veins from that of the arteries?

The pulmonary and bronchial veins anastomose with one another.

Is the circulation more or less rapid in the lung capillaries than elsewhere?

More rapid, since their area is not so great.

Why is the pulmonary vein slightly smaller than the artery?

On account of the lessening of fluid due to exhalation of moisture in respiration.

Are the movements of the lung passive or active?

They are passive, merely following the movements of the chest walls.

What are the movements of inspiration?

The side walls and front of the chest move upward and outward. By this means a vacuum is made, and air rushes in to equalize the internal and external atmospheric pressure. The antero-posterior diameter of the chest is increased by the raising of the anterior part of the ribs, the posterior ends being fixed to the spinal column. The increase in the lateral diameter is due to the outward movement of the ribs; the increase in the vertical diameter by descent of the diaphragm, the dome-shaped surface of which becomes less arched. For this reason *the diaphragm* is the *most important respiratory muscle.*

The intercostals and other muscles also aid in moving the ribs.

What are the movements of expiration?

They ordinarily take place passively by the weight of the chest, which sinks down, displacing the air. The elastic tissue of the lung aids it. When it is forced, the abdominal muscles pull down the chest.

What effect has sex on respiration?

In men respiration is largely abdominal; in women chiefly costal. In young children respiration is chiefly diaphragmatic. Diaphragmatic breathing would be impossible during pregnancy, therefore women breathe chiefly with the upper part of the chest.

Which is longer, inspiration or expiration?

Inspiration, nearly three times as long as expiration.

What sounds do we hear on listening to the chest?

The respiratory murmurs, which are produced by the passage of the air in and out of the respiratory apparatus.

What do you mean by "tidal air"?

The ordinary volume of air respired, amounting to about thirty cubic inches in the adult.

What do you mean by "reserve air"?

The air which can be voluntarily emitted after ordinary expiration. It amounts to about one hundred cubic inches.

What do you mean by "complemental air"?

The amount which can be taken in after an ordinary inspiration.

What do you mean by "residual air"?

It is the amount which remains after forced expiration, equalling about one hundred and twenty cubic inches.

What does the term "vital capacity" mean?

The greatest amount of air which can be emitted after forced inspiration, and is therefore the sum total of reserve, tidal, and complemental air. It varies with age, sex, and size. The total quantity in an adult, passing in and out in twenty-four hours, is 686,000 cubic inches; in hard-working laborers, 1,568,390 cubic inches. For every inch of height above five feet one inch, the capacity should increase eight cubic inches.

What influence has sex on capacity?

Females have less capacity than males, where the chest has the same circumference.

How many respirations a minute?

Fourteen to twenty, but the number is influenced by sex, the age, and position, also by exertion. The size of the animal governs rapidity. The mouse breathes very rapidly; the elephant only eight times per minute.

What effect has the law of the diffusion of gases on respiration?

In the vessels we have a large amount of CO_2, while in the air we breathe we have an excess of O. According to this law, therefore, the O attempts to get in as the CO_2 attempts to get out. This law also prevents the reserve and residual air from becoming laden with CO_2. The change is assisted, too, by the different temperatures of the air within and without.

What amount of work is performed by the respiratory muscles?

The work done by the respiratory muscles is estimated by Haughton at 21 foot-tons in twenty-four hours.

What changes have we produced in the atmospheric air by respiration?

1. Increase in its temperature.
2. Increase in CO_2.
3. Increase in organic matter and free ammonia.
4. Watery vapor.
5. Diminished amount of O.

The expired air is hotter than the inspired as a general rule, but on a hot day, with the atmosphere above 98.8° F., it is cooler.

The temperature varies from 97°–99½° F., according to the length of time the air remains in the lungs.

Is the amount of CO_2 exhaled constant?

It varies at all hours of the day, and is influenced by many conditions. The CO_2 given off by a normal man in an hour equals 1346 cubic inches, or 636 grains. Accordingly we have 173 grains of carbon given off in an hour, or 8 ounces in twenty-four hours.

Time of day, varieties of food, and exercise, greatly influence the amount of CO_2.

Does age affect the amount of CO_2?

Yes; CO_2 increases in amount from 8 to 32 years, while from 35 to 50 it remains stationary, or slightly falls. After 50 years it constantly diminishes. At 80 years it scarcely exceeds that of a child of 10 years.

How much O is abstracted from every volume of air?

About 4½ per cent.

What effect has quickening of the respiratory movements on the amount of CO_2?

The quicker the respirations the less CO_2 in each respiration, but the aggregate amount is increased.

What portion of the expired air contains the most CO_2?

That of the last half of expiration.

What effect has the condition of the atmosphere on the amount of CO_2?

More CO_2 is given off when air is moist than when it is dry.

What influence has the time of day on the relative amounts of CO_2 and O?

During the day more CO_2 is exhaled than O is taken in; while at night the reverse is the case. In other words, there is a reserve fund of O stored up at night to meet the exigencies of the day.

Is a very large amount of watery vapor given off by the lungs?

Yes; almost enough to saturate the expired air. The amount equals 6 to 27 ounces in twenty-four hours. The average amount is from 9 to 10 ounces.

Does ammonia exist as a physiological constituent of all expired air?

No; it does not. It is chiefly derived from decomposition products in the mouth.

THE NERVOUS MECHANISM OF RESPIRATION.

Is respiration purely an involuntary act?

No, it is not; since we can "hold the breath," or breathe rapidly or slowly, superficially or deeply, as we choose. That it is involuntary to a great extent is proved by the fact that one does not stop breathing when asleep or unconscious.

Respiration is governed by a centre, the respiratory centre, in the medulla oblongata near the calamus scriptorius.

What keeps this centre active?

It is kept active by the condition of the blood. If the amount of O is too small the centre sends out impulses and increases respiration.

What do you mean by eupnœa, apnœa, and dyspnœa?

Eupnœa is normal breathing; apnœa is a condition in which too much O is absorbed into the blood, and is readily produced by forced artificial respiration. *Remember*, that the use of the word apnœa to indicate a condition in which breathing has ceased from the ordinary causes, is incorrect. Breathing in apnœa ceases from the excess, not the lack, of oxygen. Dyspnœa is labored or difficult breathing.

What effect has the pneumogastric apparatus on respiration?

If both vagi are cut the respirations become somewhat deep and full. If these nerves are stimulated the respirations become very rapid and violent.

Is this change due to a direct transmission of the stimulus along the nerves to the lungs, or to a reflex wave to the respiratory centre?

It is due to a reflex wave to the respiratory centre. *Remember*, that the vagus nerves are made up of both efferent and afferent fibres. Also *remember* that not only do we have an efferent and afferent set of fibres, but that the afferent fibres are made up them-

selves of two sets of fibres, one of which, the central end of the superior laryngeal branch, after it has been cut, when stimulated slows the respirations, while stimulation of the central end of the vagus itself quickens the respirations. When the nerve is stimulated the impulse goes upward to the centre, and from there is irradiated down to the organs.

Sighing is a long inspiration. When great attention is being paid we speak of "shallow breathing." In other words, we almost forget to breathe. Sighing always follows this condition, and makes up for the shallow breathing before it.

Hiccough is a sudden inspiration due to descent of the diaphragm.

Coughing is expiratory.

Sneezing is expiratory, but is preceded by a full inspiration.

In speaking we expire.

Sobbing consists of a series of short inspirations, after each of which the glottis is closed.

Laughing is a series of short and rapid expirations.

DIGESTION.

What three forms of digestion have we?

Salivary, gastric, and intestinal.

What is the function of salivary digestion?

To convert starch into sugar.

On what does the gastric digestion act?

On the proteids, converting them into peptones.

What part of digestion is carried on in the small intestine?

The fats are prepared for assimilation and the proteids converted into peptones.

The salivary secretion is derived from what three glands?

The submaxillary, sublingual, and parotid. The mucous glands present in the mouth are solely for the purpose of lubrication.

Describe the characteristics of the saliva?

It is a mixture of the secretion of the three glands named, and is a slightly turbid, tasteless fluid of a distinctly alkaline reaction. The specific gravity is 1.004 to 1.008. It contains five-tenths per cent. of solids, the greater part of which are organic, such as mucin, which produces the viscidity, traces of albumen and globulin, and a peculiar ferment, *ptyalin*. The inorganic constituents are salts, the chief one of which is sulpho-cyanate of potash, which may be readily perceived by its odor when saliva is kept for a short time in a test tube. The other portions of the saliva are made up of salivary corpuscles (which are rounded, protoplasmic masses containing nuclei or coarse granules which show Brownian movements), epithelial cells, and various forms of microörganisms.

How much saliva is secreted in twenty-four hours?

From 7 to 70 ounces.

What is the difference between parotid saliva and the others?

It contains more ptyalin, a smaller amount of urea, traces of a volatile acid, and some inorganic constituents, as salts of soda and potash; it is much thinner than is the secretion of the submaxillary or sublingual glands.

Describe the submaxillary saliva.

Submaxillary saliva is markedly alkaline, tenacious, and contains mucin; it contains much less ptyalin than does parotid saliva.

Describe the sublingual saliva.

Sublingual saliva is more sticky and cohesive than either of the others, and contains much mucin, salivary corpuscles, and sulphocyanate of potash.

What is the nerve supply of the salivary glands?

The *submaxillary* glands are supplied by the chorda tympani, which is derived from the facial nerve. It also receives filaments from the superior cervical ganglion of the sympathetic, and from the submaxillary ganglion,

Remember, that the chorda tympani contains two sets of fibres: 1st, true *secretory* fibres; 2d, *vaso-dilator* fibres.

The sympathetic also contains two sets of fibres: 1st, true secretory; 2d, vaso-constrictor fibres.

The *sublingual* glands are supplied by the same nerves as supply the submaxillary. The *parotid* glands are supplied by branches of the facial which join the auriculo-temporal branches of the fifth pair of cranial nerves.

What is the effect of section of the chorda tympani?

The flow of saliva is very greatly decreased.

What is the effect of stimulation?

Increased salivary flow and increased glandular vascularity.

What is the effect of stimulation of the facial nerve at its origin in the floor of the fourth ventricle?

It increases the salivary flow from the submaxillary gland.

What is the effect of stimulation of the sympathetic?

It causes a decrease in the salivary flow, with contraction of the bloodvessels and consequent decrease in vascularity.

Does the increase in salivary flow depend upon increased vascularity?

No; since if all the bloodvessels going to the gland be tied, secretion is still increased either when the chorda tympani is stimulated, or when the sympathetic is paralyzed; under these circumstances the extra liquid required is obtained from the lymph vessels and spaces. Atropine and daturine are drugs which decrease salivary secretion by depressing the chorda tympani peripherally.

Remember, that mere increase in vascularity in the salivary glands does not of necessity increase the flow of saliva. The only influence which increased vascularity exerts is a greater supply of liquid which escapes from the gland rather by leakage than by secretion.

Is the pressure in the excretory ducts of the salivary glands very great?

Yes; Ludwig has found that the pressure in these ducts may be

twice as great as the blood-pressure in the carotid itself. The pressure in Wharton's duct may equal 200 millimetres of mercury.

What is the cause of the great pressure in the salivary ducts?

It is due to the secreting power of the cells in the gland.

What change in temperature occurs in the gland?

During secretion the temperature of the gland rises, so that it is often warmer than the arterial blood.

How do you produce increased salivary flow from the parotid?

By stimulation of the facial nerve after it has joined the auriculo-temporal branch of the fifth or trifacial nerve, or reflexly by stimulation of the glosso-pharyngeal nerve.

In what way is secretion brought about when food enters the mouth?

Reflexly through the lingual branch of the glosso-pharyngeal and the inferior maxillary branch of the trifacial or fifth nerve, which carry the impulses up to the centre in the medulla.

What effect has section of the chorda tympani on this reflex?

If the chorda tympani be cut previous to the introduction of a substance into the mouth no increase of flow comes from the glands which it supplies; but if the sympathetic be cut the reflex, although partially interfered with, is not prevented.

What is the physiological action of saliva?

Its most important action is its *diastatic* or *amylolytic* action, or, in other words, the transformation of starch into dextrin, and of dextrin into sugar.

What do you mean by the term diastatic?

The power which certain substances have of acting on starch and converting it into sugar.

Upon what does the diastatic power of saliva depend?

Upon *ptyalin*.

Is the ptyalin destroyed when it acts?

Scarcely at all, for it acts by catalysis, or its mere presence.

What is the sugar called which is formed by the action of the saliva?

The sugar formed by the action of saliva on starch is called maltose, which differs from ordinary glucose by containing one less molecule of water. Finally, the ferment acts still further, and the maltose is converted into grape sugar proper.

What is the object of boiling starchy foods?

In order to break up the cellulose coverings of the starch granules, and enable the diastatic ferment to attack the starch.

What are the mechanical uses of saliva?

It keeps the mouth moist, facilitates speaking and the mastication of food, also the movements of the tongue. It dissolves certain substances, and renders them capable of being tasted; by mixing with food it forms a soft bolus which is easily swallowed and digested.

What is the function of mastication?

We divide, by this means, the food into small pieces, biting it off by the incisors, tearing it off by the canines, and grinding it up by the molars. Soft food is broken up by the tongue pressing it against the roof of the mouth. By this means the digestive fluids may attack the food more readily.

What is the function of the tongue in mastication?

To keep the food between the teeth, in which it is assisted by the muscles of the lips and the buccinator muscles.

In what way is deglutition accomplished?

1. The aperture of the mouth is closed by the orbicularis oris.

2. The jaws are pressed together by the muscles of mastication.

3. The tip, middle, and root of the tongue, one after the other, are pressed against the hard palate, thereby propelling the food backward. Just at this time the levator palati draws the soft palate upward and backward, completely closes the posterior openings of the nasal cavities, and the intrinsic muscles of the larynx firmly close the rima glottidis.

4. After the anterior palatine arch is passed, it is prevented from returning to the mouth by the palato-glossi muscles, lying in the anterior pillars of the fauces.

5. The bolus is now urged on, first, by the action of the superior constrictors of the pharynx, next the middle, and third the inferior constrictors.

6. Having reached the œsophagus, it is urged on by the outer longitudinal and the inner circular non-striped muscular fibres, which contract peristaltically. Recent experiments show that this peristalsis only occurs on forced deglutition, the food ordinarily being projected into the œsophagus by the voluntary muscles.

What is the nervous mechanism of deglutition?

The centre for swallowing is in the medulla oblongata. The efferent nerves which govern deglutition are: the hypo-glossal, which supplies the hyoid or tongue muscles; the glosso-pharyngeal and vagus nerves to the pharyngeal plexus, which supply the constrictor muscles; and the facial and fifth, which supply the fauces and palate. The movements of the œsophagus are governed both afferently and efferently by the vagus, which also acts with the superior maxillary branch of the trifacial. The afferent vagus filaments for the first part of deglutition, are the pharyngeal branches of the anterior laryngeal branches.

THE STOMACH.

What are the movements of the stomach?

When the stomach is empty it lies with its greater curvature downward and its lesser upward; when it is full the greater curvature swings forward against the abdominal wall, while the lesser curvature approximates itself to the spinal column.

What other gastric movements have we?

We have two distinct varieties of gastric movement different from the two mentioned: the first is a *rotatory* or *churning* movement whereby the walls glide over the food, these movements occur periodically and last for several minutes, their function is to moisten the food by the gastric juice and break it up; the other is

the *peristaltic* movement whereby the food is pushed out into the duodenum through the pylorus.

What are the intrinsic and extrinsic nerves of the stomach?

Auerbach's plexus is the motor portion of the apparatus. The left vagus supplies the anterior surface of the stomach, the right vagus supplies the posterior surface.

Describe the gastric juice.

It is a tolerably clear, colorless fluid (straw-colored), of acid reaction, sour taste, and peculiar characteristic odor; it is not rendered turbid by boiling and resists putrefaction for a long time; its specific gravity is 1002.5. The quantity secreted in twenty-four hours amounts to from eight to fourteen pints.

What does the gastric juice contain?

First, *pepsin*, the characteristic nitrogenous hydrolytic ferment, which dissolves proteids; second, *hydrochloric acid*, the chief acid present; also small amounts of lactic acid. The latter, however, is not secreted, but is due to decomposition of carbo-hydrates in the stomach.

Which cells secrete the greatest amount of pepsin?

Those at the cardiac end of the stomach.

Does pepsin exist in the glands ready formed?

According to most physiologists it is due to the presence of a compound known as pepsinogen, which forms pepsin as soon as it comes in contact with hydrochloric acid in the stomach.

What is the function of lactic acid?

It digests the proteids in much the same manner as does hydrochloric acid.

Does secretion go on constantly in the stomach?

No. Only on the entrance of stimuli, such as food, etc.

What change takes place in the gastric mucous membrane on the entrance of food?

It becomes red and the circulation more active.

What happens to the gastric juice when the food passes out of the stomach into the alkaline intestine?

It is neutralized and part of the pepsin reabsorbed.

What is chyme?

The mixture of food and gastric juice.

What effect has gastric juice upon proteids?

It changes the proteids first into a substance known as syntonin or acid-albumen, which is immediately changed again into propeptone or hemi-albuminose or para-peptone. The para-peptone is now converted into peptone, which is absorbed into the blood from the small intestine and immediately converted back again into proteids, and so deposited in the tissues.

Does pepsin suffer any change when acting?

It acts chiefly by catalysis, but is partially destroyed.

(For properties of peptones and para-peptones, see page 19.)

Is any albumen absorbed unchanged?

According to Yeo, a considerable quantity of albumen is absorbed unchanged, both from the stomach and intestines.

What other special ferment have we in the stomach?

The milk-curdling ferment.

What is the action of the gastric juice on carbo-hydrates?

It has no effect on starch, inutin, or the gums. Cane-sugar is slowly changed by it into glucose, while the fats are broken up, according to Cash and Ogata, into glycerine and fatty acids.

Why does not the stomach digest itself?

There is much discussion in regard to this point, and it cannot be decided positively. Most physiologists teach that the protection which the coats of the stomach, during life, seem to have is due to the constantly circulating alkaline blood through them. This seems likely, since when the blood ceases to circulate, as in death, the stomach often digests itself. On the other hand, if the leg of a living frog or the ear of a living rabbit be put into a gastric fistula or into artificial gastric juice it will be digested.

What gases have we in the stomach?

Those which are derived from the air which is swallowed with the saliva and those which regurgitate from the duodenum. Besides these we have gases which arise in cases of dyspepsia from fermentative and putrefactive changes in the food.

What is the mechanism of vomiting ?

It is caused by contraction of the walls of the stomach, whereby the pyloric sphincters are closed. It occurs most easily when the stomach is distended, and in infants, owing to the peculiarity of the position of their stomachs, the regurgitations of milk are due to scarcely more than reversed peristalsis. In children, therefore, the abdominal muscles do not always aid in the expulsion of food. In adults they always do.

In what way is vomiting produced ?

Vomiting is produced either by an action on the peripheral ends of the nerves of the stomach or by direct action on the vomiting centre in the medulla.

What effect has section of the vagi on vomiting ?

It prevents it.

Do we ever have bile in vomit ?

Frequently when the vomiting is so severe as to cause the bile to flow out of the duodenum into the stomach.

What is the movement called by which food is passed along through the intestines ?

Peristalsis.

In what portion of the intestinal tract is peristalsis most marked ?

In the small intestine.

What is peristalsis ?

Peristalsis is the constantly moving onward of a contractile wave along the wall of the gut, or, in other words, is the progressive narrowing of the tube from above downward.

Do the movements of the stomach and intestine continue during sleep ?

Some physiologists believe that they do; others that they do not. The matter is largely one of opinion, but it is probable that the first opinion is the correct one.

What do you mean by reversed peristalsis?

A condition in which the peristaltic wave travels from below upward, the cause of which has been supposed by some to be due to the fact that one band of the muscular fibres in the gut misses a contraction.

What are the functions of the muscular coat of the intestine?

To carry on peristalsis.

What nervous influence is exercised over intestinal movements?

Auerbach's plexus is the automatic motor centre which lies between the muscular coats and produces peristaltic movements in sections of the gut removed from the body. Meissner's plexus is much less important, supplying only a few motor fibres to the muscular coats, and a few motor and sensory fibres to the muscularis, mucosæ, and intestinal glands.

What do you mean by aperistalsis?

An absolute abolition of peristaltic movement. Normal peristalsis is known as *euperistalsis*. When peristalsis becomes very violent it is known as *dysperistalsis*.

What influence has the circulation of the blood on peristalsis?

Violent peristaltic movement is produced by interrupting the circulation of blood in the wall of the gut, whether the stoppage is due to congestion or anæmia of the parts. This is the cause of the marked peristalsis preceding death.

What are the inhibitory nerves of the gut?

The splanchnics, which, however, also contain motor filaments.

What effect has stimulation of the splanchnics on peristalsis?

If the blood supply is normal it slows or prevents them. If abnormal, it increases them. The reason of this is that the inhibitory fibres of the splanchnics are paralyzed by venous blood in the gut, but the motor fibres are not.

PANCREATIC DIGESTION.

Describe the pancreatic juice?

Pancreatic juice is thick, transparent, odorless, and saltish in taste. The saltish taste is due to the presence of sodium carbonate; if acid be added CO_2 is liberated. It acts powerfully as a digestive agent.

What is the appearance of the pancreas when at rest and at work?

During digestion it is red and turbid, and at other times pale and anæmic.

What is the function of the pancreatic juice

It contains at least four hydrolytic ferments and is, therefore, a most important digestive fluid.

What are these four pancreatic ferments?

(1) The *diastatic action* is caused by a ferment known as *amylopsin*, a substance which seems to be identical with the ptyalin of the saliva.

What is the difference between the action of this ferment and ptyalin on starch?

It is much more powerful than ptyalin.

(2) The *tryptic action*, which is caused by the presence of a substance known as trypsin, or pancreatin, which acts on proteids converting them into peptones, or, as they are sometimes called, tryptones. The intermediary product between a proteid and a tryptone is alkali-albumen, corresponding to the acid-albumen of gastric digestion.

What are leucin and tyrosin?

Substances normally found in the small intestine produced by a too prolonged action of trypsin on its self-formed peptone. They are crystallizable nitrogenous bodies.

What are skatol and indol?

Strong, stinking decomposition products resulting from the continuation, pathologically, of this action of trypsin on peptone.

What is the difference in the manner in which trypsin acts on albuminous matters from that of the gastric juice?

In gastric digestion fibres of meat swell up before they are dissolved. In pancreatic digestion they do not swell up but become eroded.

What reaction is necessarily present for the pancreatic action to take place?

An alkaline reaction.

What is the alkali commonly present?

Sodium carbonate, the presence of which is as necessary to the pancreatic action as hydrochloric acid is to the peptic action.

What two forms of tryptones have we?

One known as anti-peptone the other as hemi-peptone.

What is the action of the pancreatic juice on fats?

It first forms them into a fine emulsion, and secondly causes them to take up a molecule of water and split up into glycerine and fatty acids. The action of the pancreatic juice is due to the *third ferment*, known as *steapsin*.

According to Kühne and Rorferts the pancreas contains, fourth, a *milk-curdling ferment*. The four are, therefore, as follows: amylopsin, trypsin, steapsin, and the milk-curdling ferment.

At what time is the pancreatic juice poured out?

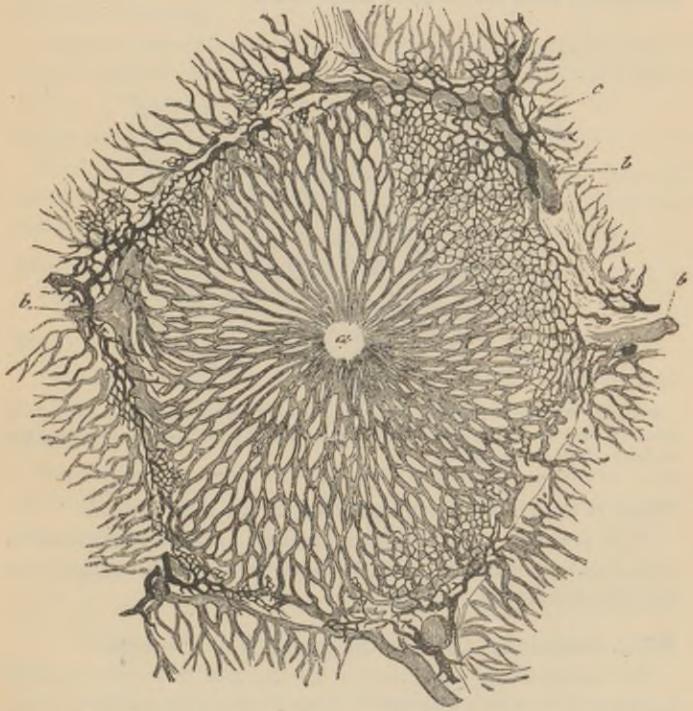
On the entrance of food into the small intestine coming from the stomach.

THE LIVER.

The anatomy of the liver is so closely concerned in its physiological functions that an outline seems necessary at this point. It will be remembered that the liver is made up of many little livers known as lobes and lobules, each lobule being a perfect gland in itself. The bloodvessels are derived from two sources, *first*, the *venous*, which enter by means of the *vena porta;* and which, branch-

ing, give off numerous *interlobular vessels* or *veins* forming dense plexuses around the lobules. Branching off from these interlobular vessels are the capillaries which converge from the centre of the lobule, forming elongated meshes, between which are rows of cells.

FIG. 2.

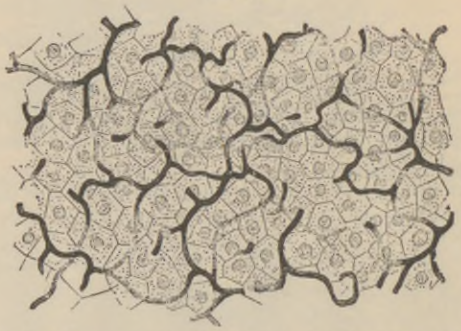


Section of lobule of liver of rabbit in which the blood and bile capillaries have been injected (after CADIAT). *a*. Intralobular veins. *b*. Interlobular veins. *c*. Biliary canals beginning in fine capillaries.

These capillaries on reaching the centre of the lobule form the interlobular vessel or central vein, which again joins together with

others and forms the radicles of the hepatic veins. The *second* set of bloodvessels are branches of the *hepatic artery* which dip down between the lobules to nourish the whole gland tissue whatever it may be. The *third* set of vessels which are present are known as the bile-ducts, which, arising from the centre of the lobule join one another and form the interlobular ducts which anastomose and finally form the common biliary duct.

FIG. 3.



Section of the liver of the newt, in which the bile ducts have been injected, and can be seen to form a network of fine capillaries around the liver cells, the outlines and nuclei of which can be seen.

What is the chemical composition of the liver cells?

First, proteids or albuminous matters. *Second,* glycogen, or animal starch, which is a true carbo-hydrate, and is changed into sugar by a diastatic ferment.

What conditions influence the quantity of glycogen?

The eating of large quantities of starch, milk, fruit, or cane-sugar increases it greatly, while purely albuminous or fatty diets decrease it greatly.

What are the sources of glycogen?

It is probably derived from the carbo-hydrates of the food.

What are the functions of the liver?

The functions of the liver are three—the secretion of bile, the formation of glycogen, and the destruction of worn-out blood cells.

What is the use of glycogen in the body?

It is not really known.

Describe the bile.

Bile is a yellowish-brown or dark green transparent fluid with a neutral reaction and a bitter taste. Its specific gravity is 1.026 to 1.032.

What does bile contain?

First, mucus, which makes it viscid, and which comes from the walls of the gall-bladder. Second, the bile acids, glyco-cholic and tauro-cholic acids, which unite with soda, forming cholates.

Which of the bile acids is most abundant in man?

The tauro-cholic acid.

What is Pettenkofer's test for bile?

Add concentrated H_2SO_4 drop by drop, then add a ten per cent. solution of cane-sugar when a reddish purple color is struck.

What is Heintz's test?

Heintz's test consists in adding nitric acid, when a play of colors results.

What are the bile pigments?

Bilirubin, which is yellowish-brown; *biliverdin*, which is green; *bilifuscin*, *biliprasin*, and *hydro-bilirubin*, the last being the normal coloring matter of the feces.

What is cholestrin?

Cholesterin is an univalent alcohol which occurs in the yolk of eggs, and in solution in the bile.

Is the secretion of bile a mere filtration of substances already in the blood?

No; it is a true secretion, being produced by the cells of the glands.

What is the quantity of bile secreted per day?

About seventeen ounces.

What is the difference between the contents of the blood-stream in the hepatic vein and the portal vein?

The hepatic vein contains more sugar (?), cholesterin, and blood-corpuscles, and less albumen, fibrin, free hæmoglobin, fats, water, and salts.

In what way is the coloring matter of the bile obtained?

By destruction of worn-out blood corpuscles.

What are the functions of the bile?

The emulsification of the fats, the lubrication of the walls of the intestine, and to increase the osmotic power of the wall of the gut in order to facilitate the absorption of fats. It also prevents to a very considerable extent decomposition and stimulates peristalic action.

What is the fate of bile in the intestine?

Some of it passes out with the feces, and part is absorbed and eliminated as urobilin. The cholesterin is given off with the feces, and the bile salts are for the most part reabsorbed by the gut.

Have the other juices of the small intestine any digestive power?

They probably have some power in the solution of the proteids, and perhaps a diastatic action.

What is the fate of the salivary, gastric, and pancreatic ferments?

Ptyalin is destroyed in the stomach by the acid pepsin, and the milk-curdling ferment by the alkaline salts of the pancreatic and intestinal juices and by trypsin, the diastatic ferment of the pancreas by acid fermentation in the large intestine.

What is the function of the large intestine?

It absorbs the liquids from the fecal matter coming from the small intestine.

What is the amount of feces in twenty-four hours?

Six to twenty ounces according to the character of the food.

ABSORPTION.

The mucous membrane of the whole alimentary canal is capable of absorption, some portions more so than others.

In what two ways does absorption occur?

By means of the blood-capillaries and the lacteals.

What substances are absorbed by the capillaries and what by the lacteals?

The first absorbs sugars and proteids, the lacteals the fats.

What portion of the gastro-intestinal tract carries on the greatest amount of absorption?

The upper half of the small intestine.

What is the position of the lacteal?

It lies in the axis of the villus, and is surrounded by a blood-vessel and a vein. The lacteals anastomose in the sub-adenoid tissue of the gut, and finally form lymphatic networks which end in the receptaculum chyli, the beginning of the thoracic duct which opens into the subclavian vein on the left side near the junction of the jugular. The villi are possessed of unstriped muscular fibres, which aid in emptying the lacteal, and the nerves which supply them are derived from Meissner's plexus.

What three forces are at work in the absorption of digested food?

Endosmosis, diffusion, and filtration.

What do you mean by endosmosis and diffusion?

Endosmosis is the change which occurs between two fluids which are capable of forming an intimate mixture with each other through an animal membrane, but never between two fluids which do not form a perfect mixture, such as oil and water. Diffusion is the mixing of two liquids placed one over the other in a vessel without the presence of a septum.

What is the law in regard to the diffusion of crystalloids and colloids?

Crystalloids will diffuse into colloids, but colloids will not diffuse

into crystalloids. Filtration occurs in the small intestine simply by the pressure which is exerted upon the fluid by the contraction of the walls, and also by a negative pressure or suction produced by the villi.

What is the influence of the nervous system on absorption?

Our knowledge is limited, but it has been found that after extirpation of the semilunar ganglion of Budge, or section of the mesenteric nerves, the intestinal contents became very fluid, which may be due to diminished absortion.

ANIMAL HEAT.

What do you mean by the term animal heat?

The temperature at which the body of a warm-blooded animal is maintained.

What is the normal temperature of man?

98⅝° F.

Is it constant in all persons?

It varies but a fraction of a degree.

Do all animals have the same temperature as man?

No; birds have as high as 107° F., and dogs as high a temperature as 103° F. In the lower animals the bodily temperature of members of the same species often varies.

Upon what does the temperature of cold-blooded animals depend?

Upon the temperature of the surrounding medium.

What conditions influence bodily temperature?

Age, sex, period of day, exercise, climate and season; food and drink also influence it.

What is the effect of age?

The temperature of a newborn child is one degree above that proper to the adult. In full adult life the temperature is lower than at any other time since it rises again in old age.

What effect has the period of day?

The variation may equal one to one and a half degrees, the minimum late at night or early in the morning; the maximum late in the afternoon.

What is the effect of exercise?

It raises the temperature; but physiologists differ as to the actual amount of increase thus, some state that the rise of temperature produced by exercise never raises the general bodily temperature more than about 1° F., while others believe that it raises it much more. Those who think the actual general rise is slight, believe that the great rise occurring in tetanus, where all the muscles contract, is due to some other concomitant pathological condition. Students must be governed in regard to this point by the opinion of their instructor. Climate and season have very slight influence over the bodily temperature.

What variations in bodily temperature may we have in disease?

In fever we may have a temperature as high as 106° and 110°, or even 115° F. In Asiatic cholera it sometimes falls to 77° or 79°.

What difference is there in the temperature of different portions of the body?

The surfaces of the hands and feet are cooler than any other portion of the body, while the liver often is as high as 105° F.

From what source is animal heat derived?

The ultimate source is contained in the potential energy taken into the body with food and with the oxygen during respiration, but the amount of heat formed depends upon the amount of kinetic energy liberated. The energy of the food stuffs may be called "latent heat." (For definitions of these terms, see Bodily Metabolism.)

What are the direct sources of heat?

The blood during digestion becomes laden with more carbon, hydrogen, and oxygen than is needful for the repair of the tissues, and these gases uniting with the sulphates develop heat by chemi-

cal means very rapidly, while the rest of the heat of the body is more slowly developed by a slower combustion. The brain, the muscles, and the glands manufacture heat, so that venous blood leaving one of these parts is warmer than arterial blood.

Is there any difference in the heat-producing properties of different food stuffs?

Fat are particularly heating, giving more kinetic energy.

What is the nervous mechanism of animal heat?

In the brain is seated a heat centre whose function it is to direct the rapidity of combustion or the development of heat in the body. Governing this centre are two others, the inhibitory heat centre (Wood), whose function it is to prevent a too rapid production of heat, and the accelerator heat centres (Sachs and Aronsohn), whose function it is to increase the production of heat.

What two functions govern the temperature of the body?

Heat production and heat dissipation. Heat production consists in the manufacture of a certain number of heat units or calories in a given space of time in the body, while heat dissipation is the function by which a certain number of heat units are given off from the body to the surrounding atmosphere or medium.

What is the effect of increased heat production and decreased dissipation?

Increase in temperature, or, in other words, fever.

What is the effect of a decrease in heat production or an increase in heat dissipation?

A fall of temperature. *Remember* that these two functions balance one another and that disorder of either of them either raises or lowers bodily temperature.

Under what circumstances is the dissipation of heat increased?

By cold surroundings, by conditions which bring large quantities of heat to the surface of the body, and by contact of the body with substances which readily conduct the heat away.

What keeps the temperature of the body uniform?

The circulation of the blood, which distributes the heat very evenly.

What conditions of the vasomotor system influence the distribution of heat?

Local dilatations of the bloodvessels produce increased temperature of the part and increased heat dissipation, and, indirectly, increased local heat production.

What is the function of the perspiration in regard to bodily heat?

By its evaporation it aids enormously in the dissipation of heat when heat is formed in or added to the body too rapidly.

Why can a person stand a high heat in a dry atmosphere better than in a moist atmosphere?

Because in a dry atmosphere the perspiration is evaporated so rapidly that the heat is readily dissipated.

How high a temperature may the human being stand in an absolutely dry atmosphere?

According to Blagden, a temperature of 198° to 211° F. was supported in dry air for several moments, and on one occasion he stood 260° F. for eight minutes, having trained his skin to excessive secretion. Workmen in English iron furnaces sometimes stand on a furnace floor which is red hot and the air of which stands at 350° F. Chabert, the so-called "fire-king," is said to have stood from 400° to 600° F., according to Morrant Baker.

Which one of the animal tissues is the best protector against cold?

The fatty layer, which nearly always occurs in varying amounts under the skin in all warm-blooded animals, and forms a protective covering whereby the conduction of internal heat is almost impossible.

Fibrous tissues conduct heat more readily in the direction of their fibres than at right angles. The bones are the next best conductors of heat, and are followed by blood-clots. The spleen, liver,

cartilage, tendon, muscle and elastic tissue, and nails follow as conductors of heat. The skin is a poor conductor of heat.

What influence has starvation on the bodily temperature?

It lowers it greatly.

What effect has sleep and hemorrhage on temperature?

In those persons who sleep during the day and work at night the typical course of the temperature is inverted from that which has been already stated as normal. Hemorrhage causes at first a slight fall in temperature, and after that a rise of several tenths of a degree, which is curiously usually associated with a chill or slight rigor. Several days after this the temperature falls again.

What is the cause of the fall of temperature after hemorrhage?

The interference with oxidation.

What effect has the artificial cooling of animals?

It produces great depression, but voluntary and reflex movements are not abolished. The pulse falls from 100 to 150 to 20 beats per minute, the blood pressure falls, the respirations become shallow, and death occurs with spasms and signs of asphyxia.

What is the asphyxia due to?

Failure of respiration: for if artificial respiration be employed at this time the temperature rises fifteen to twenty degrees. Landois asserted that if in addition to artificial respiration external warmth be applied, animals apparently dead for forty minutes can be resuscitated.

What is hibernation?

A condition in which an animal has all its vital processes temporarily in abeyance. Respiratory and intestinal movements cease completely and the cardio-pneumatic movements alone sustain the slight exchange of oxygen in the lungs. If a warm-blooded animal be cooled to 30° F., it wakes before freezing. Varnishing the skin of an animal increases heat dissipation so enormously that death occurs, which is put aside if external heat be applied.

THE KIDNEYS.

What are the kidneys?

Compound tubular glands.

What is the function of the kidneys?

Their function is the secretion of urine.

What is the purpose of the large amount of fat around these organs?

It acts as a protective.

What is the size of the adult kidney?

About four and four-tenths of an inch long, three inches thick, and two inches wide. In the male it weighs from four to six ounces, in the female from four to five and a half ounces.

Of what two portions is the kidney made up?

The parenchyma, consisting of the outer or cortical layer, and the inner or medullary layer. The medullary layer is also sometimes called the pyramidal portion.

Into what two divisions is the medullary portion divided?

It is subdivided into the boundary layer of Ludwig and the papillary portion.

What appearance has the cortical portion of the kidney when torn?

It presents a granular aspect, due to the presence of the Malpighian corpuscles. Striæ are also seen, due to the medullary rays.

What is the difference between the boundary zone or layer of Ludwig, and the papillary portion of the kidney?

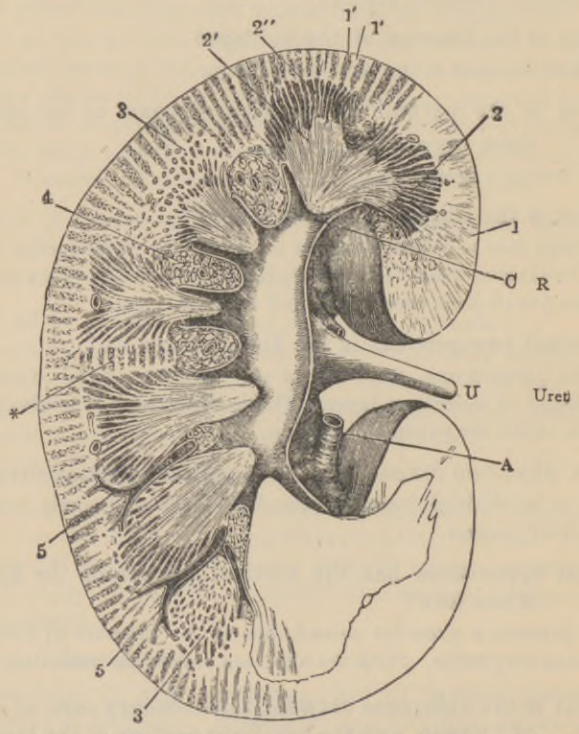
The boundary zone is darker, and often purplish in color, while the papillary zone is nearly white, and uniformly striated. The striæ merge into the apex of the pyramid.

Which is the least pliable, the cortex or medullary portion?

The medulla of the kidney is less pliable than the cortex. This

is due to the greater amount of connective tissue, and the bundles of straight tubes which may be traced at regular intervals, running upward, and becoming smaller and smaller as they pass toward the periphery.

FIG. 4.



Longitudinal section through the kidney (after TYSON and HENLE). 1. Cortex. 1'. Medullary rays. 1''. Labyrinth. 2. Medulla. 2'. Papillary portion of medulla. 2''. Boundary layer of medulla. 3. Transverse section of tubules in the boundary layer. 4. Fat of renal sinus. 5. Artery. * Transverse medullary rays. A. Branch of renal artery. C. Renal calyx. U Ureter.

In what portion of the kidney is the labyrinth?

That portion of the cortex which occurs between the medullary rays is called the labyrinth, owing to the arrangement of its tubules.

How many pyramids have we in each kidney?

Usually about eight or twelve. The pyramids are sometimes called those of Malpighi or Ferrein. The apices of the pyramids are directed toward the pelvis of the kidney, while their bases are directed toward the cortex, and each one of them opens into a small saccule or calyx, which in turn forms with others a dilated pouch, situated at the pelvis of the kidney, forming the beginning of the ureter.

How many times do we have the pelvis of the kidney divided?

First, into two or three divisions, and then again into eight or twelve smaller ones, which are called calyces.

What is the function of a calyx?

It receives the point of one pyramid, generally, but sometimes two pyramids empty into one calyx.

What do you mean by the tubuli uriniferi?

Fine, very elongated tubes, composed of a nearly homogeneous membrane, and lined by epithelium possessing the power of secretion. These tubes are, on the average, one six-hundredth of an inch in diameter. They begin at the Malpighian corpuscle in the cortical portion of the kidney, and, after passing through many convolutions, finally end in the pyramidal bodies, from the papilla-like point of which the urine drops into the saccules already mentioned.

In what portion of the kidney do we find the tubuli uriniferi?

Both in the medullary and cortical portions.

Into how many divisions are they divided?

Fifteen.

Is there any difference in the function of each division?

Certain sections are supposed to secrete certain substances.

What is the glomerulus or Malpighian body?

It is composed of a small tuft of bloodvessels covered with a

layer of cells and surrounded by a membranous covering, known as Bowman's capsule, which is the beginning or dilated extremity

FIG. 5.

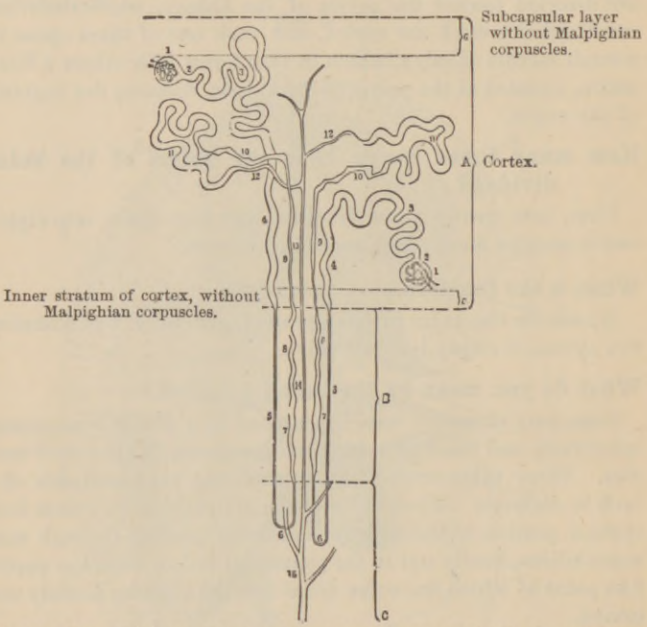


Diagram of two uriniferous tubules. (TYSON and BRUNTON, after KLEIN and NOBLE SMITH.) 1. Malpighian tuft surrounded by Bowman's capsule. 2. Constriction, or neck. 3. Proximal convoluted tubule. 4. Spinal tubule. 5. Descending limb of Henle's loop. 6. Henle's loop. 7 and 8. Ascending limb of Henle's loop. 9. Wavy part of ascending limb of Henle's loop. 10. Irregular tubule. 11. Distal convoluted tubule. 12. First part of collecting tube. 13 and 14. Straight part of collecting tube. 15. Excretory ducts of Bellini.

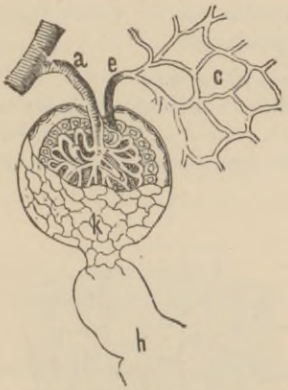
of the uriniferous tubule. They are apparent to the naked eye, in the cortical portion of the kidney, as little red points. Their average diameter is $\frac{1}{120}$th of an inch.

What is the function of the glomerulus or Malpighian tuft or corpuscles?

According to most physiologists, the Malpighian tuft secretes the

liquids and salts of the urine, while the epithelial lining of the uriniferous tubules secretes urea and uric acid, or any substance which taken into the body is eliminated by the kidneys.

FIG. 6.



Bowman's capsule and glomerulus (after LANDOIS). a. Vas afferens. e. Vas efferens. c. Capillary network of the cortex. k. Endothelial structure of the capsule. h. Origin of convoluted tubule.

What peculiar arrangement have we in the blood supply of the Malpighian tuft?

The blood passes, by means of the afferent vessel or artery, to the Malpighian tuft and enters it, giving off immediately a capillary network. At the other side of this capillary network a vessel goes off, which, as a general rule, does not leave the Malpighian body on the opposite side from the entrance of the artery, but finds its exit from the same opening as that by which the artery entered. The uriniferous tubule, however, is given off from the Malpighian body on the opposite side from that at which the artery enters and the efferent vessel leaves.

The capsule of Bowman, or the beginning of the uriniferous tubule, may be considered as a sac, into which is secreted the liquid by the Malpighian tuft.

Is the efferent vessel called a vein?

The efferent vessel after leaving the Malpighian body forms a

second capillary network, twisting around the uriniferous tubules. Not until these capillaries come together do they form one vessel, known as the *vein*.

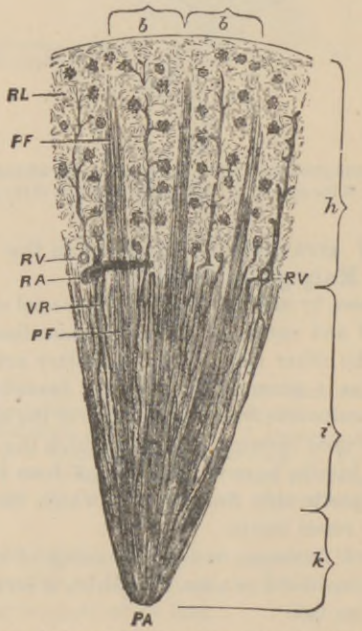
Why is the efferent vessel smaller than the artery?

It is somewhat smaller for the reason that it loses some of its liquid in the Malpighian body.

What other vessels have we?

Besides the efferent and afferent vessels, we have those known as the vasa recta, which, instead of being concerned in any way with the Malpighian tufts, pass directly out of the kidney, through the medullary portion.

FIG. 7.



Longitudinal section of kidney (after LUDWIG and TYSON) PF. Pyramids of Ferrein. RA. Rranch of renal artery. RV. Lumen of renal vein receiving an interlobular vein. VR. Vasa recta. PA. Apex of a renal papilla. *b*, *b*, embrace the bases of the renal lobules.

What is their function?

Their function is to afford a side stream for the blood in cases of congestion, so that all of it will not of necessity pass to the parenchyma of the organ.

What other vessels carry on a side stream?

Another side stream, which is less important, but for the same purpose, is produced by the fine interlobular arteries which, as they approach the surface of the kidney, communicate with the capillaries of the external capsule.

In what way is the kidney nourished?

By bloodvessels which dip down from the capsule, and from the vasa recta.

What are the nerves of the kidney?

They are derived from the renal plexus and the lesser splanchnics.

Do these nerves govern secretion, or only the blood supply?

We know that they govern blood supply, but it is not proven that they influence secretion.

What effect has increased blood pressure on the urinary secretion?

According to most of the text-books, increased blood pressure increases urinary flow, and vice versa; but recent investigations have seemed to prove that blood pressure has no very great influence over the kidney. The urine which is increased by pressure, contains less solids, proportionately, than urine formed by stimulation. "Pressure" urine is scarcely more than a leakage, and not a true secretion.

What is the function of the ureters?

To carry the urine from the pelvis of each kidney to the bladder.

Do the ureters possess any power of urging on the flow?

Yes; they have a slight peristaltic movement, and are supplied by motor and sensory nerves, the sensory nerves showing their presence in the human being when a calculus is being passed.

How long does it take the wave of contraction to travel along the ureters from the kidney to the bladder?

About one-tenth of a second.

In what way do the ureters enter the bladder?

Obliquely. They enter the external wall of the bladder at one point, pass between its coats for a short distance, and then open on its inner surface.

In what way is this opening arranged?

A small papilla with a valve-like action, permits the urine to flow out but not to return, and the oblique manner in which the ureter enters the bladder forms a sharp bend in that tube which acts as a valve, particularly when the bladder is distended.

What mechanical arrangement have we to prevent leakage from the bladder?

At the neck of the bladder the circular muscular fibres are strongly developed, and act as a sphincter, and in addition to this is the muscle known as the sphincter of the urethra, which also acts in very much the same way. *Remember!* Both these muscles must relax before urination can take place.

What is the function of the bladder?

To retain the urine until a sufficient quantity has been collected to pass, in order that a constant dribble may not take place.

What is its capacity?

About one pint.

In what condition is the mucous membrane of the bladder when the bladder is empty?

It is thrown into rugous folds.

What is the cause of the movement of the urine?

First, it is formed under high pressure in the kidney; second, gravity, when the person is erect, aids its passage; and, third, the muscles of the ureter contract rhythmically, and so aid its onward flow. This movement of the ureter is reflex, and is due to the presence of the urine in it.

Do both kidneys act constantly?

No; they act alternately.

What influence has the ingestion of small or large quantities of water on the urinary flow?

During thirst it amounts to but two or three drops every minute, when drinking it often runs in a steady stream.

In what way is the urine discharged from the bladder?

By contraction of its muscular coats, which, it will be remembered, run in all directions.

What muscles aid in the voluntary act of urination?

The respiratory muscles and abdominal muscles. The diaphragm is fixed, and the act is completed by the accelerator urinæ muscle, which quickens the stream.

In what portion of the spinal cord is the centre for the bladder?

In the lumbar region.

What other muscle aids in the expulsion of the last drops of urine, other than the accelerator urinæ?

The bulbo-cavernosus.

What is the nervous mechanism of urination?

The sphincter vesicæ is kept in a state of contraction by the motor centre governing it in the cord.

When the urine collects in the bladder a sensory impulse travels to the cord and brain, and the brain and cord in turn send down motor impulses which contract the muscular walls of the bladder, while a second impulse relaxes the sphincters.

Where is the spinal centre for urination situated?

About the point of origin of the third, fourth, and fifth sacral nerves.

THE URINE.

How much urine is secreted in twenty-four hours?

About three pints in the normal adult.

At what time of the day does the minimum secretion take place?

Between 2 and 4 A. M.

At what time of the day does the maximum secretion take place?

Between 2 and 4 P. M.

What are some of the causes that diminish the quantity of urine?

It is diminished by increase in the sweat, diarrhœa, thirst, non-nitrogenous food, diminution of blood-pressure, and certain diseases.

What are the causes which increase its quantity?

It is increased by increased blood-pressure, by copious drinking, by exposure to cold, by the use of nitrogenous food, and various conditions of the nervous system. Various drugs also influence the quantity.

What is the specific gravity of the urine?

It varies from 1.005 to 1.015 to 1.025. The minimum specific gravity occurs after copious drinking and may be 1.002; the maximum after profuse sweating, and may be 1.040. The mean specific gravity is 1.020.

What ready, but not strictly accurate, method have we for determining the amount of solids in a given specimen of urine?

By the use of Christison's formula, which consists in multiplying the last two figures of the specific gravity by 2.33, which will give the amount of solids in one thousand cubic centimetres.

What is the color of the urine due to?

The color depends on the matters present in it, chiefly urochrome and urobilin, a derivative of hematin. The color varies greatly, but the difference in intensity is chiefly governed by the quantity of water which is present.

What is the cause of the slight cloudiness which appears in the bottom of a vessel in which urine is placed for a length of time?

It is due to mucus, which is chiefly derived from the bladder.

What is the taste and odor of urine?

Its taste is slightly alkaline or bitter; its odor characteristic and aromatic. The odor, however, is altered by various causes, particularly by the administration of drugs.

What is the reaction of the urine?

It is acid, owing to the presence of acid phosphate of soda. After standing for a while the acidity is increased, due to fermentation of the mucus and other similar products, and, at the same time, with this increase in acidity, urates and free uric acid are deposited.

Under what circumstances outside the body does the reaction become alkaline?

After it has become acid it changes to an alkaline reaction, owing to the presence of ammonium carbonate derived from alterations of the urea. At the same time, a strong ammoniacal odor is noticeable, and fetor, with deposits of triple phosphates and alkaline urates, appears.

Does the reaction of the urine vary in different animals?

In most herbivora it is alkaline and turbid, but this difference depends not upon a different mode of secretion, but upon the variety of diet.

Into what three forms is the urine passed at different times divided?

Urinæ potus, urinæ cibi, and urinæ sanguinis.

What is the difference between each one of these?

Urinæ potus is secreted immediately after drinking, urinæ cibi after a solid meal, and urinæ sanguinis is that which is secreted early in the morning when neither food nor drink has been ingested.

What is the chief solid of the urine?

Urea is the chief solid constituent, and it is the most important ingredient since it is the substance by which the nitrogen of decomposed tissue is given off.

What is the result when this urea is not freely eliminated from the body?

It produces the condition known as uræmia, in which the patient has convulsions and low muttering delirium ending in death.

Does urea exist in a state of solution, or in a solid form in the urine?

In a state of solution.

What is its appearance in the solid state?

It forms delicate, silvery acicular crystals.

What is the quantity of urea excreted in twenty-four hours?

About five hundred grains.

Is the quantity of urea per day influenced by diet?

Yes. Nitrogenous or animal foods increase the urea, while a purely vegetable diet decreases it.

Is there any difference in the amount secreted by males and females?

Males secrete more than females, while middle-aged persons secrete more of it than the very young or old. *Remember*, however, that children secrete more in proportion to their weight than do grown persons.

What is the origin of urea?

It is derived from two sources: first, portions of unassimilated elements of nitrogenous food; second, from the breaking down of tissue, or tissue waste.

Does urea exist, to a certain extent, preformed in the blood, or do the kidneys manufacture it from the blood?

Some of it certainly exists ready formed, the kidneys merely extracting it.

What is uric acid?

An acid which appears, as a general rule, in small quantities in the urine of the human being, and which is entirely absent in the cat tribe. The quantity of it varies greatly in different animals. In birds and serpents its amount greatly exceeds that of the urea.

In what way is the quantity of uric acid increased?

By nitrogenous food, but decreased by vegetable food. In gout it is deposited around the joints as the urate of soda.

From what does uric acid arise?

From the destruction of albuminous matters. The relation between urea and uric acid is not well understood.

What is hippuric acid?

It is found in man and is allied to benzoic acid. Benzoic acid is eliminated as hippuric acid.

What are extractives of the urine?

They consist of kreatin and kreatinin, two crystallizable substances derived from muscle metamorphosis.

What are the saline matters of the urine?

H_2SO_4 in the urine forms a compound chiefly or entirely with soda or potash, thereby forming salts. The phosphoric acid also combines and forms salts.

The breaking down of what tissues increases the amount of phosphates in the urine?

The nervous tissues.

How are the chlorides formed?

The chlorine combines with ammonia and potash to form chlorides.

Do gases exist in large quantities in normal urine?

No; in very small quantities. They are chiefly CO_2 and nitrogen.

What pathological conditions of the urine occur?

Albuminuria is a condition in which a certain amount of albumen is allowed to escape from the system by the kidneys. At one time the presence of albumen in the urine was considered to be pathognomonic of Bright's disease, but it has been proved that it may exist physiologically for a short time after the ingestion of large quantities of albumen. Hematuria is a condition in which there is blood in the urine, the blood coming from the kidney or any portion of the urinary apparatus.

What is hæmoglobinuria?

A condition in which free hæmoglobin occurs in the urine. Remember, that hæmoglobinuria is not hæmaturia.

What is choluria?

The presence of bile in the urine. It occurs in certain conditions in which the circulation of the portal vein is disordered, or after the ingestion of certain poisons, as, for example, phosphorus.

What is glycosuria?

Glycosuria is the presence of sugar in the urine. It is termed diabetes mellitus.

What is the cause of diabetes mellitus?

It is either produced by a lesion occurring in the diabetic centre in the floor of the fourth ventricle, or is due to disorder of the circulation of the liver whereby the sugars ingested and manufactured in this organ are improperly distributed.

What is chyluria?

It is a condition in which the chyle from the digestive tract is passed out in the urine.

What is diabetes insipidus?

A condition in which a very large quantity of liquid, of a low specific gravity and containing no sugar, is passed.

THE SKIN.

What are the chief functions of the skin?

It acts as an external integument for the protection of the deeper tissues, as a sensitive organ in the exercise of touch, as an important excretory and absorbing organ, and plays a highly important part in the regulation of the bodily temperature.

Of what does the skin consist?

The skin consists of a layer of vascular tissue named the *corium, derma,* or *cutis vera,* covered by a layer known as the *cuticle* or *epidermis.* Underneath and within the corium are embedded several organs with special functions, as follows: the *sudoriferous* glands, the *sebaceous* glands, and the hair follicles, while on its surface are sensitive papillæ.

Are the appendages of the skin, known as the hair and nails, formed from the corium or the epidermis?

They are modifications of the epidermis.

What layer of the epidermis contains the pigment in colored races?

The layer known as the rete mucosum.

From what portion of the skin does the papillæ arise?

They are conical elevations of the corium or true skin.

What is the function of the papillæ?

Nearly every one of them contains a nerve ending, thereby increasing the peripheral sensibility. (For the corpuscles of touch, etc., see the Special Senses, "Touch.")

What is the function of the cuticle?

It protects the papillæ from injury and forms a check on undue evaporation from the skin. The manner in which it protects sensibility is made evident when we remember the tenderness of those areas, where, by constant rubbing, the epidermis is rubbed off.

What is the function of the sudoriferous glands?

They pour out the sweat on the surface of the body through ducts which at first are spiral but which, as they approach the surface, become straight.

Are the sudoriferous glands the glands which secrete the familiar odors in the axilla and elsewhere?

No; the glands which are odoriferous are like them save that they are larger and have very short, straight ducts.

What is the difference between sweat and perspiration?

Sweat is applied to the liquid which is secreted so fast that it collects in drops; perspiration, to the moisture which is continuously and unconsciously given off by the skin.

What is the function of sweat and perspiration?

They aid in the dissipation of heat by their evaporation and thereby reduce the bodily temperature.

How much watery vapor is excreted by the skin in twenty-four hours?

From one and one-half to two pints.

How much CO_2 is lost in this manner per day?

An amount which is almost $\frac{1}{150}$ to $\frac{1}{250}$ of the amount exhaled by the lungs, and which differs enormously according to the conditions surrounding the individual, and exercise, food, and drink.

What other impurities are given off by the skin other than CO_2?

Urea and inorganic salts.

Is the excretory function of the skin important?

Exceedingly so, if interfered with it may produce death by throwing too great a strain on the kidneys, for *remember* that the skin is a supplementary organ to the kidneys.

In what ways may the flow of perspiration be increased other than by exercise or exposure to heat?

If a localized vaso-motor palsy occurs sweating sometimes takes

place; section of the cervical sympathetic produces copious sweating of that side of the head.

What are the objects of the sebaceous glands?

They secrete a lubricating fluid or oily matter which keeps the skin soft and pliable.

What is the vernix caseosa?

That sebaceous matter which covers the skin during intra-uterine life.

What is the function of hair?

It acts as a protection from cold, as when on the head, and protects the skin from friction in the axilla or on the pubis. Besides protecting the head from changes in temperature, it wards off blows which might otherwise be serious in their results to the more vital tissues.

What is the function of the nails?

To protect the ends of the fingers from injury or the sensory papillæ of the finger tips from contact with harsh, rough objects, which, if it occurred constantly, might deprive them of their delicacy of touch.

Can absorption of certain substances take place rapidly through the skin?

Very rapidly. A familiar example of this is the ptyalism produced by mercurial inunctions.

SECRETION.

What is secretion?

The separation from the blood of some product, directly or indirectly, by the vital process peculiar to a gland or membrane. This product is called an *excretion* when it is passed out of the body as waste, or a *secretion* when it carries out some function in the animal economy.

Give a good example of an excreting gland?

The kidney.

Give an example of a secreting gland.

The pancreas or mammary gland?

(For the manner in which secretion is carried on in each gland, see questions on each subject.)

THE MAMMARY GLANDS.

What changes take place in the mammary gland during gestation?

It becomes much larger, the areola around the nipple increases in width and deepens in color, the veins become more prominent, while the lobules can be plainly felt.

How many lobes has the mammary gland?

From fifteen to twenty, each one of which is divided into several lobules made up of acini.

What is the function of the lactiferous ducts?

They carry the secretion to the nipple, on which they open by a number of orifices. Just before they enter the nipple they dilate, forming little sacs which collect the milk.

In what way are the fat globules of milk formed?

They are supposed to be the results of a physiological fatty degeneration of the cells lining the acini and ducts.

(For Milk, see Articles used as Foods.)

THE BODILY METABOLISM.

What do you mean by the term Bodily Metabolism?

Those phenomena by which all living organisms are capable of taking substances derived from their food into their tissues, and making them an integral part of their own bodies; further than this, metabolism includes the breaking down of these tissues, and the removal of the results of their destruction; the first half of the process is termed *assimilation*, the second half *excretion*.

Does the body merely assimilate sufficient food to replace exactly those particles which are destroyed, or does it do more than this, and act as a storehouse, from which, on a sudden strain, energy may be derived?

It acts as a storehouse of potential energy, which, when necessity arises, it may transform into kinetic energy.

What do you mean by potential energy?

That energy which possesses the power to move, but is quiescent.

What do you mean by the term kinetic energy?

Potential energy, when exerting its influence, either by producing motion or preventing it, is called kinetic energy; in other words, potential energy is latent, kinetic energy is active. A coiled watch-spring held firmly represents potential energy, but if the pressure is removed, its force is transformed into kinetic energy.

GENERAL VIEW OF THE MOST IMPORTANT SUBSTANCES USED AS FOOD.

How much of the body is made up of water?

58.5 per cent. of the body consists of water, which is continually taken in and given off.

What is the purpose of water in the organism?

The processes of digestion and absorption require the presence of water for the solution of the food, and it is also used to carry off the effete products. So much water exists in the tissues of all animals that Hoppe-Seyler has put it that all organisms live in water.

Milk.

What is the use of milk and its preparations?

Milk forms a complete typical food, in which are all the constituents necessary for life and growth.

What are the constituents of milk?

In every ten parts of proteids we have ten parts of fats and twenty parts of sugar.

Describe some of the characters of milk.

It is an opaque, bluish-white liquid, with a sweetish taste and a characteristic odor.

What is this odor due to?

Probably to the peculiar volatile aromatic substances derived from the cutaneous secretion of the glands.

What is its specific gravity?

1.026 to 1.035.

What is the reaction of human milk?

It is always alkaline; cows' milk may be alkaline, sometimes acid, or even neutral. The milk of carnivora is always acid.

What are milk globules?

Small, highly refractive, oil globules floating in a clear fluid, the milk plasma. The white color of milk is due to their presence.

Of what do the globules consist?

Of fat or butter, surrounded by a coating of casein.

What is the effect of churning on these milk globules?

This coating of casein is broken, and the butter globules are allowed to run together.

What does the milk plasma contain aside from the globules?

It contains free casein, serum-albumen, and, to a less extent, a body resembling albumen, the lacto-protein of Millon and Liebermann.

What other substances have we in milk?

Galactin, albuminose, and globulin; very minute traces of peptone are also present. Milk sugar, a carbohydrate resembling dextrin, and urea and extractives complete the list of its constituents. *Remember*, that the casein is the albuminous portion

of milk while the butter globules make up the hydro-carbon portion.

When milk is boiled, what changes take place in it?

The serum-albumen coagulates, while the surface also becomes covered with a layer of casein which has become insoluble.

Is raw or boiled milk most digestible?

The raw milk; if nature had intended that boiled milk should be more digestible than raw milk, raw milk would have been formed with the same conditions present that exist in boiled milk.

Upon what does the coagulation of milk depend?

Upon the coagulation of its casein.

What salt in milk keeps the casein in solution?

Calcium phosphate; which is, of course, destroyed by the acid of the stomach. *Remember*, that milk coagulates in the stomach, not on account of the acid, but owing to the presence of a milk-curdling ferment. (See page 58, Digestion.)

What causes the spontaneous coagulation or souring of milk?

It is produced by the development of lactic acid, which is formed from the milk sugar by the action of the *bacterium lacticum.*

What is the difference between human milk and cow's milk?

It contains less albumen, and the albumen it does contain is more soluble than that in cow's milk. It also contains more sugar and fats than does cow's milk.

What is colostrum?

It is the substance which is secreted at the beginning of lactation, and contains much serum-albumen, and very little casein, while all the other substances, specially the fats, occur in large amount.

What is the purpose of colostrum?

Containing, as it does, a large amount of fat, it acts as a purgative, and sweeps out the meconium and other effete products from the alimentary canal of the infant.

Are gases found in ordinary milk?

Only in minute traces.

What salts are found in milk?

The potash salts are much more plentiful than the soda salts; there is also a large amount of calcium phosphate present.

What is the purpose of the calcium phosphate?

It is necessary in the formation of the bones of the infant.

What difference is there in the composition of milk at various times?

That drawn last is always richer in butter, while if the ducts are emptied frequently the butter decreases but the caseine increases.

Are eggs a typically complete food?

They are not as complete a food as is milk, but are the most typical food next to milk.

What is the object attained by cooking flesh?

It breaks up to a certain extent the elastic coverings of the muscular fibre, softens the connective tissues, and renders it more tender and easy of digestion.

In the vegetable foods, what are the chief nitrogenous substances?

Gluten is the most abundant nitrogenous substance present, and occurs immediately under the husk.

How many groups of foods are necessary for the maintenance of health in man?

Five.

What substances make up these groups?

First, the *starches*, which are used for the purpose of adding heat to the body, and also fat; second, the *fats*, which are used for the purpose of maintaining the bodily heat and retaining it; third, *albuminous* foods, whose function is to add force to the system; fourth, *water*, which is necessary for the carrying out of the vital processes; and fifth, *salts*, which are also absolutely needful for the maintenance of health.

What is the absolute amount of the different food-stuffs required by an adult in twenty-four hours?

It varies enormously according to the surrounding conditions, but, as a general rule, it should contain 130 grammes of proteids, 84 grammes of fats, and 404 grammes of carbohydrates. *Remember*, that the carbohydrates should always be greatly in excess of the nitrogenous principles.

What effect has the withdrawal of all forms of food-stuffs, with the exception of one particular class, upon nutrition?

The animal wastes, and finally dies with very much the same symptoms as would follow starvation.

The manner in which effete products are taken up and excreted has already been considered (see Circulation, Respiration, and the Kidney and Urine).

What process goes on during starvation?

All food being taken away from the body the organism is required to abstract at first the unimportant tissues in order to keep up its vital processes. After this the wasting becomes marked, and the bodily weight falls. Weakness, the result of the breaking down of vital tissues, comes on, and finally death, after all substances capable of supplying force in the body have been used up, save those actually concerned in the vital processes.

How long will the average adult survive without food?

About twenty-one to twenty-four days, although cases are on record of survival for forty-one days.

How much bodily weight is lost before death?

Four-tenths of the bodily weight.

Are fats ever formed from proteids?

Yes; as an example of this, the cow does not consume as much fat in a day as she gives in butter.

THE MUSCLES.[1]

What is the function of the muscles?

To produce movements, which vary according to the rapidity and power of their contraction.

In what way do the voluntary muscles act upon the bones?

As levers. They are often attached to the short arm of the lever, and while this is apparently a disadvantage, since under these circumstances greater force is required to lift a given weight, it, in reality, is of the greatest service, since slight contractions of muscles cause very extensive and rapid movements of the part.

How many orders of levers are met with in the movements of the different bones of the skeleton by the muscles?

All three; and in some cases all three occur at the same joint.

Give an example of the first order of levers.

When the triceps is the power which draws upon the olecranon, thus moving the hand and forearm around the trochlea, which acts as the fulcrum.

Give an example of the second order.

This occurs when the hand, resting on a point of support, acts as the fulcrum, and the triceps pulling on the olecranon is the power which raises the humerus, upon which is fixed the body or weight.

Give an example of the third order.

This is exemplified by the action of the biceps in ordinary flexion of the elbow, in which the biceps is attached to the upper portion of the forearm.

What two varieties of muscular fibre have we?

Two; striped, or striated or voluntary; unstriped, unstriated or involuntary. The first group are moved entirely by the will-power, or by centres under the control of the will-power. The second group, solely by nervous centres over which the will-power has no direct influence.

[1] The anatomy of muscles is to be found in anatomical text-books.

What large mass of striped muscular fibre is an exception to this rule?

The heart, which, although it is made up of striped muscle, beats independently of the will. The arrangement of the heart muscle, however, is somewhat different from striped muscular fibres elsewhere.

What is the difference in the contraction of striped and unstriped muscular fibre?

The striped muscular fibre usually contracts more rapidly.

What is the consistency of muscle?

The contractile substance of muscle is so soft as to be almost fluid, being of the consistency of jelly.

What is the chemical composition of muscle?

As already pointed out elsewhere, it is impossible to determine this during life, since the analysis produces death. Muscle, however, contains the substances known as *muscle-serum* and *muscle-clot* or *myosin*, which are the result of certain chemical changes occurring after death.

What effect has coagulation of the myosin in muscle?

Its formation is followed by "rigor mortis," or post-mortem rigidity.

In what way can this coagulation be postponed?

By keeping the muscle at a temperature but a few degrees above freezing point. If a muscle be kept in this manner, pressure will cause the exudation from it of a yellow, opalescent, alkaline juice, which on still further cooling changes into a jelly.

What effect has warming of this jelly?

It passes through the stages of coagulation seen in ordinary muscle after death, producing the same fluid serum and muscle-clot or myosin.

What is this muscle juice sometimes called?

Muscle plasma, which is supposed to be the contractile matter in living muscle.

What does the coagulation of muscle plasma very closely resemble?

The coagulation of blood plasma, with the difference that the muscle clot is gelatinous and not in threads, as is fibrin. It is a globulin, and is soluble in a two per cent. solution of common salt. *Remember*, that this globulin forms the greater portion of albuminous matter in muscle.

What is the difference between the reaction of muscles before and after death?

Before death they are alkaline; after death, acid.

Of what does the serum of the muscle consist beside the albuminous principles?

1st, kreatin, kreatinin, and xanthin; 2d, hæmoglobin; 3d, grape sugar, muscle sugar or inosit, and glycogen; 4th, sarcolactic acid, made from the inosit by fermentation; 5th, carbonic acid; 6th, potassium salts; and, 7th, 75 per cent. of water.

What do you mean by the elasticity of muscle?

The degree to which the muscle can be stretched and still return to its normal length. If a given weight be applied to the end of a muscle, it is stretched a certain distance; but an additional weight or weights do not produce by any means an elongation equal to the first. The elongation, on additional strain, is constantly decreased in extent.

Is there any variation in the elasticity of muscles?

At first a strain on a muscle produces very rapid extension; but this is constantly decreased as time goes on, finally ceasing. Muscles which are fatigued are more readily stretched than fresh ones.

What difference is there between the elasticity of dead and living muscle?

Dead muscle possesses less elasticity and requires a greater weight to stretch it. It can be stretched further than living muscle, but does not return to its former length as completely as the normal muscle.

Are the muscles of the body always on the stretch, and if so, what is the object reached by this condition?

They are always on the stretch, even when passive, and act as ligaments which bind together, in a compact mass, the entire body. Muscles nearly always have opposing muscles whose function it is, when exercised, to produce opposite movements. The elasticity of these muscles, in a passive state, also opposes active contraction in the opposite muscle, which is, however, easily overcome. After the active contraction has taken place, the elasticity of the passive muscle acts as a weak spring, thereby keeping up the tonicity of the limb and preventing sudden jerkings of the body, as would occur if a muscle should contract suddenly and "take up the slack" in the opposite muscle.

What electrical phenomena have we in muscle?

In the normal living muscle we have invariably present an electric current known as the *natural muscle current.*

What circumstances influence this current?

It is greatly reduced by fatigue and loss of vital power, and is generally supposed to be absent in perfectly normal *passive* muscle lying *in situ.* As soon as the muscle is moved or disturbed by partial removal from the body the current develops.

What do you mean by "negative variation" in muscle?

If a muscle be connected with a galvanometer so as to measure its natural current and then be stimulated to a contraction by means of the nerve trunks, a marked decrease occurs in the current. The galvanometric needle swings toward the zero point, showing that the current is weakened and destroyed. This is called the *negative variation,* and precedes the change to an active condition of the muscle.

What do you mean by the irritability of the muscle?

The capability with which a muscle passes into contraction.

What are the usual causes of contraction of the voluntary muscles?

They contract ordinarily in response to impulses communicated

to them by nerves, the impulse originating in the brain or spinal cord. The will power is the most common cause of contraction of the skeletal muscles.

What other conditions may produce contractions of the muscles?

Contraction of the muscles may be produced either by the application to them directly of some irritating or stimulating substance, or by the application of stimulation to their supplying nerves.

Is it possible to cause contraction in muscular fibre which is devoid of terminal nerve filaments, or, in other words, does the contraction of a muscle necessarily depend upon the presence of peripheral motor nerves?

That muscles may be stimulated to contraction without the intervention of nerve fibres, is proved by the fact that some parts of muscles, as the lower end of the sartorius, respond energetically to all forms of muscle stimuli, though they possess no nerve endings; there are some substances, too, which produce contraction of muscles on direct application, which will not produce that contraction when applied to the nerve trunk, as, for example, ammonia. Again, the muscles will generally respond to various stimuli long after the nerve supplying them has been killed by exposure, and curare, which paralyzes the peripheral ends of the motor nerves in the muscles, in no way prevents the contraction of the muscle itself when it is directly stimulated.

What forms of muscle stimuli have we?

First, *mechanical* stimulation, as by a sudden blow or pinch, resulting in momentary transient contraction. Second, *thermic* stimulation. Contraction of the muscle takes place if the temperature be raised or lowered. This contraction, however, is scarcely identical with ordinary muscular contractions, since it is a prolonged spastic contraction of an abnormal type. Third, *chemical* stimulation, which may produce contractions by irritating mineral and organic acids, various metallic and neutral salts. Fourth, *electrical* stimulation, which is the most common form employed, and gives the most satisfactory results.

At what time during the application of an electrical current to a muscle does the contraction take place?

Remember that it takes place not while the current is passing through the muscle, but at the moment the current is turned on or turned off, or is suddenly increased or decreased in strength. A constant current of exactly even intensity may be made to pass through a muscle without exciting contraction.

Is the stimulus necessary to produce contraction in a muscle when applied to its nerve trunk, sufficient to produce the same degree of contraction in the muscle when applied to the muscle itself?

No, it is not.

What are the chemical changes resulting in a muscle during its contraction?

Its neutral or faintly alkaline reaction becomes for the moment acid, owing to the formation of sarco-lactic acid. More oxygen is taken up from the blood than when the muscle is at rest. A greater amount of carbon dioxide is given off, but the change in the quantity of CO_2 has no exact relation to the quantity of oxygen used. A diminution is said to occur in the glycogen of muscle, and a peculiar muscle sugar makes its appearance.

What changes occur in the elasticity of the muscle during contraction?

The elasticity is less than when it is in a passive state—that is, a given weight will stretch a contracted muscle more than a passive muscle, but the return to the normal length of the muscle is not so complete, or, in other words, extensibility is increased, elasticity is decreased.

What effect, therefore, has stimulation of a muscle which is overloaded by a weight greater than it can lift?

When stimulation is applied to such a muscle we get elongation instead of contraction, because of the rule just now given, namely, that the active state lessens the elastic power of the muscle.

What effect has stimulation of one part of a muscle upon the rest of the muscle?

A contraction wave passes from the part stimulated over the whole mass.

What effect has the activity of muscle fibre upon its temperature?

It raises it very markedly, the production of heat being in direct proportion to the tension of the muscle. If the muscle be kept in a state of constant activity, so that fatigue is produced, the temperature falls.

What change in shape takes place in the muscle on contraction?

It shortens, and in direct ratio with its shortening its thickness increases. There is, therefore, but little change in bulk, but considerable change in shape.

What do you mean by the "latent period"?

The short space of time which elapses between the moment of stimulation of a muscle and the beginning of its contraction. In the voluntary muscle of the frog this lasts only about one-tenth of a second.

What do you mean by the period of "rising energy"?

The space of time during which contraction occurs first slowly, then more quickly, then more slowly.

What do you mean by the term "falling energy"?

The period at which relaxation of the muscle takes place. At first slowly, then more quickly, finally, more slowly.

Is there any pause at the height of contraction before relaxation begins?

No, none at all.

Is there any variation in the rapidity of contraction of different muscles?

Yes, an enormous difference exists not only in various animals, but in the same muscles of a single individual. As an example

of the difference in rapidity of contraction in the muscles of different animals, may be mentioned the fact that while the unstriped muscular tissue of a mollusc occupies several minutes for its contraction, the muscle of the wing of a horse-fly contracts 330 times a second. The variation and rapidity of contraction differ very largely with the needs and habits of the animal.

What do you mean by the "maximum contraction" of a muscle?

The greatest shortening which can be produced by a single instantaneous impulse or stimulus.

What do you mean by the term "summation"?

If a muscle be caused to contract by a shock of medium strength it contracts to its maximum, but if a second shock be given while the muscle is contracting from the first shock, a new maximum contraction is added to that already under way. This is called the *summation* of effect.

What do you mean by the "tetanus"?

A condition of a muscle in which it apparently remains in a constant state of contraction—or, in other words, a *summation* of contractions exists. To produce artificial tetanus, impulse after impulse must be transmitted to the muscle with great rapidity, otherwise between each stimulus the muscle will partially relax or attempt to pass into the condition known as *falling energy*.

Upon what does the irritability and fatigue of a muscle depend?

This is governed by the amount of labor required and the nourishment supplied by the blood. Fatigue means lessened irritability.

THE NERVOUS SYSTEM.

What is the function of the nervous system?

It is the apparatus by which distant parts of the body are kept in constant relationship with one another so that a change of

condition in any one spot is communicated to, and may set up corresponding changes in, remote parts.

What two divisions have we of nerve fibres?

The afferent or *centripetal*, and the efferent or *centrifugal;* most nerves contain both sets of fibres.

Do nerve fibres possess the power of generating force in themselves?

They do not. Neither are they capable of originating impulses. They are functionally inactive until they receive impulses from higher nerve centres.

What is the arrangement of the sheaths of the nerve fibres?

In the centre of every nerve is a bundle of protoplasmic fibrils, always covered, and known as the *axis-cylinder;* in some nerves there is but one very thin transparent covering termed the primitive sheath, while in others there is a thick layer of fluid inside the primitive sheath in immediate contact with the axis-cylinder. The fluid, which is very viscid, is known as the *white substance of Schwann;* it is also called the *medullary sheath.*

What is the distinction between the white and the gray nerves?

The white nerves contain the white substance of Schwann, the gray nerves do not.

Which of these two varieties is the most common?

The white by far, since the gray are contained chiefly in the sympathetic system and parts of the organs of special sense.

What is the function of an afferent, centripetal, or sensory nerve?

To carry impulses from the periphery to the centre which may receive them.

What is the function of an efferent, centrifugal nerve?

To carry impulses from the centre to the periphery, which

impulses may arise of themselves in the central nervous system or be excited reflexly through a sensory nerve.

Are impulses travelling along one nerve trunk ever transferred to another nerve trunk running near by?

No, never, under any circumstances, if both nerves are intact.

How many divisions have we of efferent nerves?

First, *motor*, or nerves going to muscles causing them to contract; second, *secretory*, which call forth the activity of glands; third, *inhibitory*, which check or prevent some activity; fourth, *vaso-motor* nerves, which regulate the contraction of the muscular coat of the bloodvessels, and trophic, thermic, and electric nerves, all of which are doubtfully in existence, save the electric, which occur in animals capable of emitting electrical discharges.

What do you mean by inter-central nerves?

Inter-central nerves are those which act as bonds of union between the cells of nerve centres.

What is the velocity of nerve force?

It is about at the rate of thirty metres per second, or the speed of a fast express train, so that impulses can only travel from one portion of a man's body to another at about the same rate as an express, or about twice as fast as the fastest horse can gallop.

What do you mean by "negative variation"?

The natural current of a nerve, like that of a muscle, undergoes a diminution at the moment the nerve is stimulated; this is termed the negative variation. The negative variation travels along the nerve at just the same velocity as the impulse does from the point of stimulation, as a consequence of this the negative variation and nerve impulse are believed to be identical.

What do you mean by electrotonus?

If one of two wires leading to a galvanometer be applied to the centre, and the other to the end of the nerve so as to indicate the natural current, and at the same time another part of the nerve be placed in the circuit of a constant current from the battery, and

the current be turned on, a change is found to occur in the natural current; this is termed electrotonus.

What do you mean by the terms anelectrotonus and katelectrotonus?

Anelectrotonus is the term applied to the condition of the nerve near the anode, or positive pole, during the passage of a constant electrical current, the irritability of the nerve being *de*creased in this region. Katelectrotonus is applied to the part of the nerve near the cathode, or negative pole, the irritability being here *in*creased.

What do you mean by the irritability of nerves?

The condition which permits of the transmission of impulses from more or less powerful stimuli.

What conditions are necessary for this irritability?

A perfect supply of blood, to bring nourishment and carry away effete matters, an uninjured connection with the nerve centres, and a normal temperature.

At what portion of the nerve trunk would you apply the stimulus to produce the greatest contraction in the tributary muscle, or, in other words, at what point would you find the greatest irritability of the nerve?

At some part of the nerve distant from the muscle. The further from the muscle the more powerful is the contraction produced. The impulse seems to gather force as it goes along the nerve.

What do you mean by the "indifferent point" of a nerve?

As already stated, when a constant current is applied to a nerve its irritability is greater in the neighborhood of the cathode but is diminished in the neighborhood of the anode. Near the middle of the nerve, or rather a point about half way between each pole, we have an area known as the *indifferent point*, since at this portion the increased irritability of the cathode no longer exists, nor does the diminished irritability of the anode occur. This *indifferent point* is not *always* midway between the two poles, since variations in the strength of the current influence its position.

What are the laws of contraction?

1. In all muscles, when the current is broken, the disappearance of anelectrotonus is the cause of the stimulation. 2. When the current is made it is the appearance of katelectrotonus which causes the stimulation. 3. With the same current the contraction produced with the *making* of the current is more than the contraction which occurs on the *breaking* of the current. 4. Anelectrotonus causes *reduction* of irritability and conductivity. 5. Katelectrotonus causes *increase* of irritability. 6. With ascending currents, the portion of the nerve next to the muscle is in a state of reduced functional activity or anelectrotonus. 7. With descending currents the part of the nerve next the muscle is in a state of exalted activity—katelectrotonus. 8. These changes are much weaker with weak currents than with strong ones.

What do you mean by the term nerve corpuscles or terminals?

Those small nerve bodies or corpuscles in which nerve fibres end and through which efferent nerve fibres give off their impulses and afferent nerve fibres receive their impulses. Those which are attached to the endings of sensory or afferent nerves of the skin are known as tactile corpuscles.

PHYSIOLOGY OF THE SPINAL NERVES.

It will be remembered that thirty-one pairs of *spinal* nerves leave the vertebral canal between the vertebræ, in contradistinction to the *cranial* nerves which come out from the base of the skull, and that each pair of nerves is attached to the spinal cord by two roots known as the anterior and posterior, which becoming united pass through the intervertebral canal, forming one trunk. Just before the junction of the two roots it will also be remembered that the posterior root is enlarged by a ganglionic swelling. The spinal nerves are, therefore, sometimes called mixed nerves for the reason that they contain both efferent and afferent fibres. Those going from the anterior portion of the spinal cord carry the motor or efferent impulses, those coming to the posterior part of the spinal cord carry the afferent impulses.

What do you mean by recurrent sensibility?

If after division of a motor nerve the peripheral portion of it be stimulated some pain is felt. This is due to what is known as *recurrent sensibility*, and depends on the fact that some of the fibres of the sensory root, after having joined the motor root, instead of going as usual to the periphery, revert to the spinal cord and enter it by the motor root. This condition of recurrent sensibility is also found in some of the peripheral mixed nerves.

What is the function of the ganglia which occur on the posterior roots of the spinal nerves?

Their function is not clearly understood. There is no evidence of their being centres of reflex action, nor can they be shown to possess any marked automatic activity, but it is supposed that they preside over the nutrition of the nerve itself, for if the roots be cut off, that part of the posterior root attached to the cord degenerates, while the piece attached to the ganglion remains intact. This is not the case where the anterior or motor root is cut, since under these circumstances that portion of the nerve next the cord remains intact, while the divided portion undergoes degeneration. From this it would appear that the nutrition of the sensory nerves is governed by the ganglia, while that of the motor nerves is governed by centres in the cord itself.

THE PHYSIOLOGY OF THE CEREBRO-SPINAL NERVOUS SYSTEM.

The physiology of the cerebro-spinal nervous system includes that of the spinal cord and the medulla oblongata, the brain, and the nerves given off from each one of them, and the functions of the ganglia on those nerves.

What is the function of the membranes of the brain and spinal cord?

The dura mater is a tough membrane, and composed of bundles of connective tissue, whose function it is to enclose, and, to a certain extent, protect the nervous tissue beneath it. The arachnoid

is a much more delicate membrane, similar in structure to the dura mater; the function of which is to secrete the cerebro-spinal fluid. The pia mater consists of immense numbers of bloodvessels, which dip down and nourish the surface of the brain.

What do you mean by the neuroglia?

A special form of connective tissue which supports the nerve-fibres and the cells of the brain and spinal cord.

Of what does the spinal cord consist?

It is a cylindriform column of nerve-substance connected with the brain through the medium of the medulla oblongata, and terminating in the midst of the roots of the many nerves which form the cauda equina. It is composed of white and gray nervous matter, of which the white is situated externally, and constitutes the chief portion, while the gray occupies its central portion, and is so arranged that on the surface of a transverse section it appears like two somewhat crescentic masses, connected together by a narrow portion or isthmus.

Is the spinal cord of the same size throughout its whole length?

No; it varies greatly. It is very large in the middle and lower part of the cervical region and at the lowest part of the dorsal region, since at these two points a large number of nerve fibres are given off.

Of what does the white substance of the spinal cord consist?

Of nerve fibres with a medullary sheath.

What is the function of these nerve fibres?

The transference of impulses from cell to cell.

Of what does the gray matter consist?

Of a dense network of naked nerve fibrils with numerous ganglionic cells scattered between them. The nerve fibres in this substance also transmit impulses from cell to cell.

Does the white or the gray substance contain the ganglionic cells?

The gray substance.

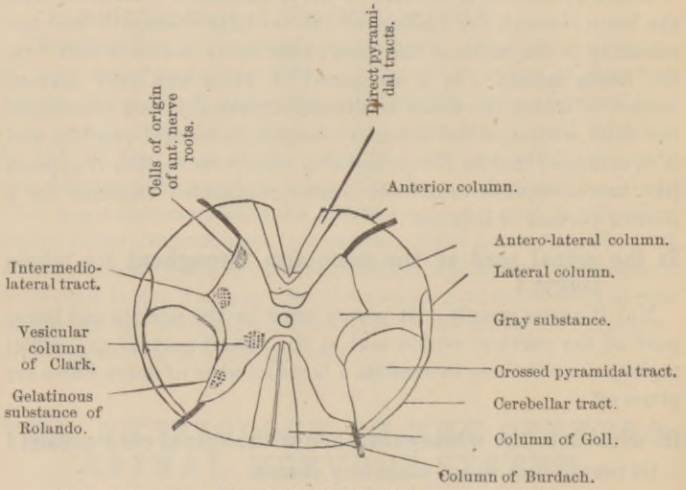
What are these cells called?

Multipolar, bipolar, or unipolar cells, for the reason that they possess processes, one or more in number, which do not divide in the same way as do the interlaced nerve fibres.

What groups of nerve cells have we in the gray matter?

1. In the anterior cornua are cells which are the points of origin for the motor spinal nerves. (See Fig. 8.)

FIG. 8.



Transverse section of the spinal cord at level of the upper dorsal vertebræ.

2. The tractus intermedio-lateralis, a group of nerve cells midway between the anterior and posterior cornua, near the external surface of the gray matter. (See Fig. 8.)

3. The posterior vesicular columns of Clark and Stilling are found in the posterior cornua near the inner surface. (See Fig. 8.)

4. The substantia gelatinosa cinerea of Rolando is scattered throughout the gray matter, but is chiefly found in the posterior cornua. (See Fig. 8.)

Into how many columns is the spinal cord divided?

Three on each side. The following scheme will illustrate this more clearly than words, particularly if the figure is also examined:

1. Anterior columns	The direct or uncrossed pyramidal tracts. The anterior ground bundles or anterior radicular zones.
2. Posterior columns	Goll's column, or the postero-median column Burdach's columns, or the posterior radicular zones, the posterior lateral columns or the funiculus cuneatus.
3. Lateral columns	The anterior and lateral mixed paths. The crossed pyramidal paths. The direct cerebellar paths.

The Functions of the Spinal Cord.

In what manner is conduction carried on by the spinal cord?

It carries the sensory impulses transmitted to it by the sensory nerves up to the perceptive centres in the brain, and the motor impulses from the brain down to the nerves which are distributed to the muscles.

Roughly speaking, what portion of the cord may be considered motor, and what portion sensory?

The anterior portion is motor; the posterior, sensory.

What difference is there in the function of the white and gray matter?

According to Schiff, and most physiologists, the gray matter transmits in all directions both sensory and motor impulses which are purely reflex in character, or, in other words, only intended to remain in the cord, while sensory impulses which are to go *to* the brain, or motor impulses which pass *from* the brain, must travel by the white matter.

It will be remembered that both the anterior motor and the posterior sensory nerve roots do not arise from the white matter, but from the horns of the gray.

The function of the gray matter in the posterior horns is, therefore, limited to the receipt and transmission of sensory impulses from the periphery to the white matter, which will conduct them to the brain, or across the cord to a motor cell to complete a reflex action.[1]

The function of the gray matter of the anterior horns is limited to the transmission of motor impulses from the white matter to the motor nerve trunks, or to the originating of a reflex movement.

What function is supposed to be possessed by the gray matter around the central canal of the spinal cord?

To transmit sensory impulses up to the brain without their having to pass through the white columns.

In what way can you prove, physiologically, that the anterior columns of the cord are motor and the posterior sensory?

If the posterior columns be destroyed, the foot may be burnt off but no signs of pain are elicited. If, upon the other hand, the anterior columns be destroyed, burning of the foot produces violent pain-cries, but the animal is unable to send the impulse from the brain to the leg and draw it away from the injury.

What is the function of the direct or uncrossed pyramidal tracts of the anterior columns and the crossed pyramidal tracts of the lateral columns?

They carry all the impulses from the central convolutions of the cerebrum, by which voluntary movements are executed.

What is the function of the direct cerebellar paths of the lateral columns?

They connect with the cerebellum directly by ascending fibres, which proceed through the restiform bodies from Clarke's columns of nerve cells in the gray matter. They connect the posterior nerve roots of the trunk (not of the extremities) with the cerebellum.

[1] For definition of a reflex movement, see page 114.

What is the function of the anterior ground bundles of the anterior columns, and the anterior and lateral mixed paths of the lateral columns?

They connect the gray matter of the spinal cord with that of the medulla, and carry reflex impulses. They also contain those fibres which are the direct continuation of the anterior spinal nerve roots which have entered the gray matter. The anterior and lateral mixed paths of the lateral columns also contain some sensory paths.

What is the function of Goll's column?

It unites the posterior roots with the gray nuclei of the posterior pyramids, otherwise known as the funiculi gracili, and carries impulses *centripetally*.

By what is the nutrition of these various conducting paths governed?

By nutritive centres, in the case of the centripetal tracts, situated in the cerebrum. In the centrifugal, or motor, tracts these centres are situated in the anterior cornua of the cord.

What classifications can we make in the functions of the nervous centres in the cord?

Their functions can be divided into *conduction, transference, reflection*, and *automatism*, or the power of originating impulses in themselves.

Give an example of conduction through a nerve centre.

If an impulse travels from a peripheral sensory nerve to a single centre in the spinal cord reflexly it may produce contraction in the muscles which are tributary to the motor centre next to it. This stimulation, if strong enough, may cause an impulse to travel to all the other centres in the cord, so that general muscular movements may take place.

Give an example of the transference of nerve force.

The pain in the knee or ankle occurring during hip disease is a good example of this condition, and is supposed to be due to the fact that the sensory nerves running from the hip carry impulses up to the sensory cells in the spinal cord, which again transfer the sensation they receive to sensory centres in direct communication with the area of the knee or ankle. Under these circumstances the brain receives the impulse from the two sets of fibres and misinterprets the real cause of the sensory impulse. The impulse, under these circumstances, may be divided into two portions, the first, which is the primary, and goes to the brain directly from the cells in communication with the hip, while the other is the secondary, and is due to the transference to other centres of the impulse before it reaches the brain. If the primary and secondary impulses reach the brain together the pain is referred to both the hip and knee.

What do you mean by the reflexion of nerve force, or reflex action?

Reflex action is due to the fact that an impulse travelling from the periphery to the body along the sensory nervé reaches the same point at which a sensory or receptive cell and a motor or expulsive cell exist side by side. Under these circumstances the sensory cell transfers an impulse to the motor cell, by conduction, which in turn starts an impulse down along its tributary motor nerve, with the result of contraction in the muscle which it supplies.

Give an example of this.

If the foot of a frog be pricked the leg which is pricked, and, to a certain extent, the other leg, are immediately jerked away. That this jerking away of the leg is not due to the fact that the brain desires to remove the leg from the irritation, is proved by the fact that if the spinal cord be cut, thereby preventing any impulses from reaching the brain, reflex action is as marked as if the cord was intact.

What is Setschenow's reflex inhibitory centre?

A centre situated in the upper portion of the spinal cord whose function it is to prevent excessive reflex action. If it were not for this centre the pricking of a pin would cause but a slight reflex contraction of the leg, while a violent blow would send such an impulse to the reflex centres that a severe convulsion or tonic spasm might result. Under these circumstances, however, the reflex inhibitory centre controls the motor centres of the spinal cord and prevents their sending out impulses which would be too violent.

What is automatism?

The originating, entirely independent of any external cause, of an impulse in a nerve cell.

What special centres have we in the spinal cord?

Centres which govern the bladder and genital organs.

What effect has irritation applied directly to the anterior and lateral white columns?

It produces muscular movements but no pain, and they are consequently excitable but insensible.

Are the posterior columns, when irritated, sensitive or insensitive?

They are very sensitive, particularly near the origin of the posterior roots.

Is this sensibility due to the presence of sensory nerve filaments belonging to these columns, or simply to the presence of the fibres of the posterior roots?

It is simply due to the fibres of the roots.

What effect has section of the antero-lateral columns?

It abolishes all power of voluntary movement in the lower extremities.

What effect has section of the posterior column?

The power of muscular coördination is lost. It is these columns which are diseased in locomotor ataxia.

Does the gray matter respond in any way under the influence of direct stimulation?

No, it does not.

What is the result of a lesion of the spinal cord in the lower part of the sacral region?

There is paralysis of the sphincters of the rectum and bladder and of the accelerator urinæ, and the compressor urethræ muscles.

What is the result of a lesion high up in the sacral region?

Paralysis of the muscles of the bladder, rectum, and anus; loss of sensation and motion in the muscles of the leg, except those supplied by the anterior crural and obturator nerves.

What is the effect of a lesion on the upper part of the lumbar region?

Loss of motion and sensation in both legs; loss of power over rectum and bladder; paralysis of the muscles of the abdominal walls. As a result of this, there is some interference with respiration.

What effect has lesion of the cervical part of the cord?

It produces palsy, as do the other lesions named, with, in addition, paralysis of all the intercostal muscles, and, as a result, great interference with respiration. There is paralysis of the muscles of the upper extremities except those of the shoulders. If a lesion occurs at the upper cervical region, death is instantaneous from respiratory failure.

The Medulla Oblongata.

The *points* to be *remembered* concerning this portion of the nervous system are as follows:

Its columns are continuous with those of the spinal cord, and each half of it may be considered to be divided into three columns or tracts of fibres, in the same manner as they occur in the spinal cord.

What difference exists between the columns here and in the cord?

They are more prominent, and separated from each other by deeper grooves.

What are these columns of the medulla called?

Pyramids; the anterior columns are called the *anterior pyramids*, those of the posterior columns *restiform bodies*.

FIG. 9.

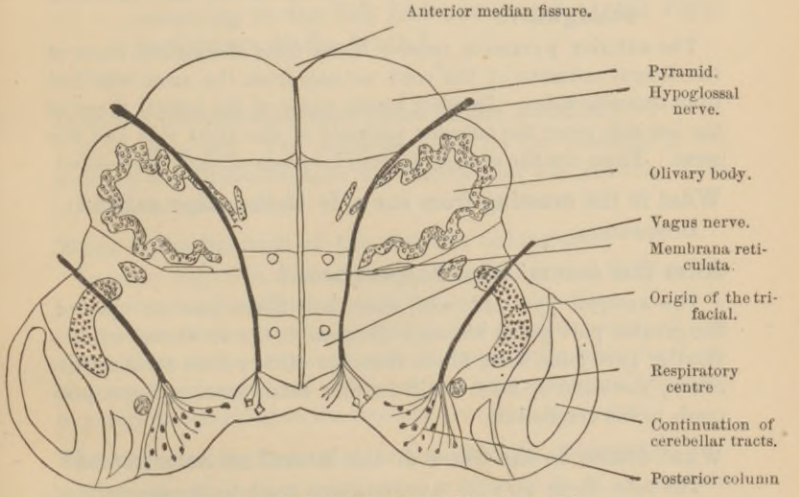


Diagram showing cross section at level of fourth ventricle.

What are the direct pyramidal tracts?

The anterior pyramids which pass directly upward to the cerebrum without crossing to the other side.

What are the crossed pyramidal tracts?

Those fibres of the lateral columns which cross to the opposite anterior pyramid.

What is the olivary body?

On the outer side of each anterior pyramid is a small oval mass of gray matter, the *olivary body.*

What is the posterior pyramid?

A small tract marked off from the posterior part of the restiform bodies on each side by a slight groove.

What forms the fourth ventricle?

The restiform bodies diverge, and by so doing lay open a space—the fourth ventricle.

What is the distribution of the fibres of the medulla oblongata?

The anterior pyramids receive fibres from the middle fibres of the lateral columns of the cord, *not only* from the same side but from opposite sides. In other words, some of the lateral fibres of the left side enter the anterior pyramid of the right side and *vice versâ.* These are the crossed pyramidal tracts already mentioned.

What is the crossing from one side to the other called?

Decussation.

After this occurs, what happens next?

The anterior pyramids with their new fibres pass on upward, the greater part going through the pons to the cerebrum, while a smaller part joins some fibres from the olivary body forming the *olivary fasciculus* or *fillet.* Still another small mass of fibres proceeds to the cerebellum.

What course do the fibres of the lateral columns pursue?

The *outer* fibres go with the restiform tract to the cerebellum, the *middle* decussate to the anterior pyramids as already stated,

and the *inner* pass on to the cerebrum along the floor of the fourth ventricle.

What is the direct cerebellar tract?

The outer fibres of the lateral columns first named.

Do the impulses of the will which arise in the brain pass down each side of the spinal cord directly and produce contractions in muscles of the same side?

No, they do not. The fibres carrying these impulses cross each other in such a way that impulses arising in the left side of the brain are made manifest on the right side of the body, while those arising in the right side of the brain are made manifest in the left side of the body.

Why is this so?

The decussation of part of the fibres of the anterior pyramids of the medulla transfer impulses across the cord.

Does this same transference of impulses take place in the sensory tract, or, in other words, is a sensation occurring in the left foot recognized in the right hemisphere of the brain?

Yes.

Does the transference take place in the medulla?

No, it does not. The posterior fibres do not decussate in the medulla, but Brown-Séquard has shown that the crossing takes place in the spinal cord.

What is the function of the medulla oblongata?

In many ways it is similar to that of the spinal cord for it carries on conduction, transference, reflexion, and *automatism*. It is in this portion of the nervous apparatus that the decussation of part of the fibres of the anterior cornua of the medulla takes place, explaining the phenomenon which has just been mentioned in regard to paralysis occurring on the opposite side from the lesion.

What special centres exist in the medulla oblongata?

First, the *respiratory centre*, whose function it is to send out those impulses which result in respiratory movements, and the

interference with which causes great disorder of respiration or death; second, it contains the centre of *deglutition* which sends out the impulses which produce the movements necessary to the acts of swallowing; third, a centre for the movements of *mastication;* fourth, the chief *vaso-motor* centre which governs the blood-vessels all over the body (see Circulation); fifth, the *cardio-inhibitory* centre for the regulation of the movements of the heart through the pneumogastrics; sixth, the *cilio-spinal* centre which governs the movement of the iris; seventh and eighth, the centres of the special senses of *hearing and taste;* ninth, the centre for speech; tenth, the centre for *vomiting;* eleventh, the centre which governs the secretion of *saliva.*

How do you know that the medulla contains all those centres which are necessary for the continuance of life?

Because the brain and cerebellum can be destroyed and yet the respiration and heart go on unimpaired.

What is the function of the pons Varolii?

It contains a large number of nerve fibres both transverse and longitudinal and is a conductor of impressions from one part of the spinal axis to another. Concerning its functions as a nerve centre little or nothing is certainly known.

What are the functions of the crura cerebri?

They are formed of nerve fibres, of which the inferior or superficial are continuous with those of the anterior pyramidal tracts of the medulla, and the superior or deeper fibres with the lateral and posterior pyramidal tracts, and with the olivary fasciculus. Each crus cerebri contains among its fibres a mass of gray substance known as the *locus niger.* They act principally as conducting organs. As nerve centres they are probably connected with the functions of the oculo-motor nerve which arises from the *locus niger,* and through which are directed the numerous movements of the eyeball. They are also connected with the coördination of other movements than those of the eye.

What is the result of injury to the crus cerebri?

Either rotatory or disorderly movements, with loss of coördination, result.

What is the function of the corpora quadrigemina?

Removal of those bodies produces total loss of vision; destruction of one of them produces blindness in the eye of the opposite side. It also produces rotatory movements of the body resembling those occurring after division of the crus cerebri, save that the movements are slower.

What is the function of the corpora striata and the optic thalami?

Injury to the corpora striata on one side prevents the communication between the will and the muscles of the opposite half of the body, so that palsy results, or, in other words, hemiplegia. The corpus striatum may, therefore, be considered as the motor connection between the cerebrum and the crus cerebri. If the optic thalamus is destroyed on one side sensation of the opposite side of the body is impaired or lost. It is, therefore, regarded as the sensory band between the cerebrum and the crus cerebri.

What are the functions of the cerebellum?

It is absolutely insensible to irritation and may be cut away without any signs of pain; its removal from the body or destruction by disease is generally unaccompanied by loss or disorder of sensibility. Animals from which it is removed can see, hear, and feel pain to all appearance as perfectly as before. It governs the coördination of movements, and while irritation of the cerebellum produces no movements at all, remarkable results are produced by removing part of its substance. As portion after portion of it is cut away the animal gradually loses the power of springing, walking, standing, or preserving its equilibrium. If laid upon its back it cannot recover its normal posture but struggles to get up, and if a blow is threatened tries to avoid it.

What results do we gain, therefore, from these experiments?

We know that the cerebellum has no connection with volition, sensation, and memory, but merely has the faculty of combining

the action of the muscles and producing thereby the movements intended by the higher nervous centres. *Remember* that the influence of each half of the cerebellum is directed to the government of the opposite side of the body, and that both halves must act in unison, or, otherwise, strange disorders of motility result.

What is the function of the cerebrum?

The cerebral hemispheres are the organs by which perception is carried on. They contain the organ of the will; they possess memory, or the means of retaining impressions of sensible influences; and they are the medium of all the higher emotions and feelings—imagination, understanding, reflection, and judgment.

How do we know that consciousness depends upon the action of the cerebral hemispheres?

If they are injured in any way, consciousness is lost—as, for example, during an apoplectic fit.

How do we know that it is in the cerebral hemispheres that the intellect is situated?

Because the higher the intellect is the greater development is possessed by the brain and because destruction of the cerebrum stops intellection. Congenital and other morbid conditions of the hemispheres always produce disorders of the intellect.

What do you mean by cerebral localization?

The determination of the areas in the cerebral hemispheres governing various portions or functions in the body.

Where is the speech centre located in the cerebrum?

In the third frontal convolution and the Island of Reil.

On which side of the brain is the speech centre best developed?

The left side.

What is aphasia?

The partial or complete loss of the power of articulate speech from causes arising in the cerebrum.

THE CRANIAL NERVES.

It will be remembered that, according to most anatomists, the cranial nerves are divided into twelve pairs.

1. What is the function of the olfactory nerve?

It is the nerve of special sense by which odors are distinguished; in other words, it is the nerve of smell. It is distributed to the mucous membrane of the nose, and arises superficially from the lower part of the frontal lobe in advance of the anterior perforated space, passing through the cribriform plate of the ethmoid bone.

2. What is the function of the optic nerve?

It is the nerve of sight, and is distributed to the retina of the eye. It arises superficially from the geniculate and quadrigeminal bodies and thalamus, and passes out through the optic foramen of the orbit. It conveys no other impulses than those of sight.

What is the effect of division of one of the optic nerves?

It produces complete blindness in the eye of the corresponding side.

What is the effect of division of the optic tract?

It produces loss of sight in the outer half of the eye of the same side, and of the inner half of the eye of the opposite side.

What is the effect of injury to the anterior part of the optic chiasm?

It causes blindness in the inner half of both eyes.

3. What is the function of the oculo-motor nerve?

It is the motor nerve of the levator palpebrarum, the superior, internal, and inferior rectus, and the inferior oblique muscle of the eye. Its superficial origin is the inner side of the cerebral crus, and it finds its exit from the sphenoidal foramen. It also supplies filaments to the ciliary ganglia from which the ciliary nerves arise, which enter the eyeball and are distributed to the circular fibres of the iris and the ciliary muscle. It governs the accommodation of the eye.

What effect has stimulation of the oculo-motor on the pupil?

It causes contraction of the pupil, internal strabismus, and muscular movements of the eye, but no pain. Section of the nerve is followed by ptosis, or drooping of the upper eyelid, internal strabismus, due to the supposed action of the external rectus muscle, and paralysis of the accommodation of the eye.

4. What is the function of the pathetic nerve?

It governs the movements of the eyeball so far as those are concerned which are produced by the action of the superior oblique muscle; it arises from the valve of Vieussens and passes through the sphenoidal foramen.

5 What is the function of the trifacial nerve?

It is a nerve of sensation, motion, and taste. It arises from the side of the pons by a smaller motor and a larger sensory root, and is divided into three divisions, the *first* of which supplies the conjunctiva, the lachrymal gland, the eyeball, the upper eyelid, the integument of the forehead, and the mucous membrane and integument of the nose. The *second* division supplies the lower lid and conjunctiva, the temple, upper lip, nose, cheeks, and teeth of the upper jaw. These two divisions are purely sensory. The *third* division supplies the muscles and skin of the lower part of the face, the muscles of mastication, the teeth in the lower jaw, the tongue, the parotid gland, and the auricle of the ear. This division contains motor, sensory, and other filaments which carry the sense of taste.

What is the effect of irritation of the larger root of the trifacial nerve?

It produces marked evidence of pain, which is always felt in the periphery of the nerve, since it will be remembered that pain arising at the origin of a sensory nerve is always referred to its peripheral filaments. Irritation of the small root produces movements of the muscles of mastication, whilst section of this root causes paralysis of these muscles. Section of the large root is

followed by a complete abolition of sensibility in the head and face, but no disturbance of motion.

6. What is the function of the abducent or sixth pair of nerves?

Motion, which results in turning the eyeball outward. They arise from the anterior pyramids, and supply the external rectus muscle of the eye. Stimulation of this nerve causes outward rotation of the eyeball, while paralysis of it causes internal strabismus.

7. What is the function of the facial nerve?

It supplies the motor filaments of the muscles of the ear, scalp, and face—platysma, digastric, and stylohyoid muscles—and arises between the olivary and restiform bodies. It finds its exit through the internal auditory meatus, the facial canal, and the stylomastoid foramen.

What is the peculiarity of the facial nerve?

It is a motor nerve in its origin, but in its course receives sensory filaments from the fifth pair and the pneumogastric. Irritation of the facial produces muscular contractions, while division produces paralysis of the muscles of the face. *Remember*, that it is this nerve which gives off the chorda tympani, that branch which supplies the bloodvessels and secretion of the sublingual and submaxillary glands and the sense of taste in the anterior two-thirds of the tongue.

8. What is the function of the auditory nerve?

It governs the sense of hearing, conducting the impulses from the exterior to the brain. It rises in the floor of the fourth ventricle, and is distributed to the labyrinth of the ear. Destruction of this nerve produces deafness.

9. What is the function of the glosso-pharyngeal nerve?

It governs the sensibility of the pharynx, and therefore influences taste. It has also motor filaments which pass to the root of the tongue, the tonsils, the soft palate, the pharynx, and the tympanum.

10. What is the function of the pneumogastric or vagus nerve?

It is chiefly made up of sensory filaments which anastomose with motor filaments from other sources. It influences deglutition, the action of the heart, the circulatory and respiratory systems, the voice, and the stomach. It arises from the fore part of the restiform body and the vagal nucleus of the floor of the fourth ventricle. The functions of its branches have been considered when studying the circulation, respiration, etc.

11. What is the function of the spinal accessory nerve?

It is made up of motor filaments, some of which pass to the vagus nerve, while others supply the sterno-mastoid and trapezius muscles. It arises from the lateral columns of the spinal cord and the gray substance within. It will be remembered that it consists of two parts, a smaller accessory root whose deep origin is in a nucleus of gray matter at the back of the medulla below the origin of the vagus, and a large spinal root from the lateral columns of the cord.

What is the effect of destruction of its medullary root?

It produces paralysis of the laryngeal muscles, resulting in aphonia, and impairs the action of the muscles of deglutition. Irritation of the spinal root produces contractions of the trapezius and sterno-mastoid muscles, but section of this branch does not produce absolute palsy in these muscles, since they are supplied by motor filaments from elsewhere.

12. What is the function of the hypoglossal or sublingual nerve?

Its function is motor and it governs all the movements of the tongue, influences mastication, deglutition, and articulate language. It rises from the anterior pyramid, the olivary body, and the hypoglossal neucleus. Irritation of it produces convulsive movements of the tongue, while division of it abolishes all these movements and interferes considerably with deglutition; articulation is considerably impaired, and mastication is performed with difficulty from inability to retain the food between the teeth.

THE SPECIAL SENSES.

What do you mean by the term "nerves of special sense"?

Those nerves which carry, as do sensory nerves, impulses from the periphery to those centres in the brain which may perceive and interpret them, and which differ from the ordinary sensory nerves in that, as a general rule, the impulses are not the result of ordinary stimulation by contact, but of one special form of irritation. As an example of this the optic nerve appreciates light, yet light can never be said to produce activity of the nervous protoplasm by contact; nor do the vibrations of air produced by sound cause any impulses to travel along any sensory nerves save the auditory; neither can we say that the olfactory nerves are stimulated mechanically by the presence of substances so small that they cannot be distinguished by spectrum analysis, but which, nevertheless, are perceived by the nostrils; this is the reason why each one of the nerves carrying the impressions of sight, smell, taste, or sound, are called *special*, since each one of them can transmit but one variety of impulse.

Do the nerves which carry these impulses of special sense differ from other nerves in their structure and ordinary capabilities?

No; they differ in no way at all from ordinary afferent nerves, with one or two exceptions.

Is the sensation recognized at the point at which the cause exists, or by the special centres in the brain?

It is recognized in the centre, but, as has been stated before, impulses in sensory nerves are always referred to the periphery, and, therefore, we are accustomed to say that we feel the burn or other injury at the spot where it occurs.

By what means is this peculiar condition in regard to sensation governed?

It is solely governed by the mind itself, which has been taught to do this as the result of education, experience, and habit, acquired by a long series of unconscious experiments in early youth.

What is necessarily present for a complete special sense apparatus?

First, a special nerve ending, only capable of being excited by special forms of stimuli; *second*, an afferent nerve to conduct the impulse from the special end organ to the nerve centre; *third*, nerve cells forming a centre, which is capable of translating the impulse received into a sensation and of referring that sensation to some local point; *fourth*, associated nerve centres capable of perceiving sensations, forming ideas, and drawing conclusions therefrom, with the object of determining the position, character, and intensity of the external influence.

The Sensibility of the Skin.

Those impulses which are received through the skin are obtained through the *sense of touch*.

Into how many divisions is this sense of touch subdivided?

First, tactile sensibility, by means of which we appreciate the slightest touch and recognize the exact point at which the skin receives the impulse. *Second*, the *sense of pressure*, by which we are enabled to judge of the compression which is being exerted on a certain area; this sense, however, is by no means so well developed as the tactile sense. *Third*, the *sense of temperature*, by which we are enabled to determine whether an object is hot or cold. This sense, also, is not perfectly developed, since for a moment we are unable to determine whether an object is hot or cold unless the eye or other special sense aids us.

What is the object of tactile sensibility?

In order that we may judge of the position, character, and shape of bodies.

Is tactile sensibility exceedingly important to the animal organism?

Very important, since without it nothing could be held firmly in the hand, and all the movements of the body would be seriously interfered with.

In what way are the nerves arranged for tactile sensibility?

The sensory nerves running to the skin are endowed with endings of various forms according to their function; these forms are divided into five varieties: *First*, the *touch corpuscles*, which are egg-shaped bodies situated in the papillæ of the true skin, directly under the epithelial cells of the rete mucosum; they vary in size considerably, according to the amount of work which they are forced to perform; in these the axis cylinder of the nerve ends. *Second*, the *end bulbs*, which are smaller than the last and differ from them in that they are only distributed to localized areas; they are made up of a little vesicle containing fluid in which the axis-cylinder terminates, the wall of the vesicle joining the sheath of the nerve. *Third*, *touch cells*, which differ from the others in that they exist in the deeper layer of the epiderm. *Fourth*, *free nerve endings*, which occur on the surface of the epithelium of mucous membranes. *Fifth*, *Pacinian corpuscles*, which are ovoid bodies made up of concentric layers of varying consistence, with a collection of fluid in the centre, in which the axis-cylinder ends.

The Sense of Taste.

In what way is taste produced?

By the contact of sapid substances with the endings of the gustatory nerves of the tongue in the various papillæ.

What are these papillæ sometimes called?

"Taste buds" or "taste goblets."

Is it possible to taste a dry substance?

No; when a dry substance is placed on the tongue the moisture dissolves or moistens at least some of it.

What proof have we that this is so?

If the tongue be thoroughly dried no taste is perceived.

Where is the chief sense of taste situated?

In the tongue.

What other surfaces aid the tongue in tasting?

The soft palate and its arches, the uvula, tonsils, and upper pharynx. The hard palate has little taste power.

What is the nerve supply of the back part of the tongue?

The glosso-pharyngeal.

What is the nerve supply of the tip of the tongue?

The lingual branch of the trifacial nerve.

What portion of the tongue perceives taste the best?

The back portion. The tip and middle of the tongue are not so well endowed with nerves.[1] The sense of smell aids the sense of taste when eating. If the nostrils be closed and the eyes shut no distinction can be exercised between a piece of apple, potato, or onion on the tongue.

Do certain areas of the tongue taste certain bodies?

Yes. The sulphate of quinine is scarcely noticed at the tip, at the back it is very well perceived. Sugar, on the other hand, is best tasted on the tip of the tongue.

The Sense of Smell.

How is the sense of smell excited?

By fine bodies floating in the atmosphere.

What effect on smelling has drying of the nasal mucous membrane?

It impairs the power of perceiving odors very greatly.

What is the object of sniffing?

In order to draw over the nerve endings a current of air containing the odor.

In what way are the olfactory nerves arranged?

Most of these nerves are distributed to the mucous membrane of the middle and upper meatus of the nose. The mucous membrane

[1] For the muscular movements of the tongue, see Mastication.

in this area is not covered by motile cilia such as are found in the rest of the nasal cavity; it is less vascular and of a peculiar yellow hue. The extreme delicacy of smell can best be understood when we remember that Valentin has estimated that two-millionths of a milligram of musk is sufficient to excite the olfactory nerves of man. In other animals this sense is even more acute.

The Sense of Sight.

The Eye and its Coverings

What is the function of the eyelids?

To protect the eyeballs, and to distribute moisture over them constantly, thereby preventing drying.

How are they formed?

They are movable folds of skin, each of which is kept in shape by a thin plate of yellow elastic tissue.

What is the function of the eyelashes?

To prevent the entrance of foreign bodies, especially when the lids are half closed.

In what way do they differ from ordinary hairy growths?

They possess tactile sensibility, which causes, reflexly, the lids to close tightly when a foreign body touches them.

What is the purpose of the Meibomian glands along the edges of the lids?

To lubricate them, and prevent irritation from the tears.

In what portion of the orbit is the lachrymal gland placed?

In the upper and outer angle.

What is the use of the lachrymal gland?

To secrete liquid, which will lubricate and keep the eye moist. When an excessive secretion takes place it runs over the lower lids, in the form of tears.

On what side of the orbit does the lachrymal secretion escape?

On the inner side, through the puncta lachrymalia, one of which

exists in each lid; thence it passes into the lachrymal sac, and from there through the nasal ducts into the nose.

What function has the lower eyelid which is not possessed by the upper lid?

It acts as a gutter along which an excess of the tears may flow; when one cries the gutter overflows.

What is the function of the orbicularis palpebrarum muscle, and what is its nerve supply?

It closes the eye, and is supplied by the facial nerve.

What muscle opens the eye?

The upper lid is raised by the levator palpebrarum superior, which is supplied by the oculo-motor nerve.

In what way does the ending of the optic nerve differ from any other sensory nerve?

It is enclosed in a specially arranged organ, the *eyeball.*

What is the object of the eyeball?

For the purpose of so directing the rays of light that they strike in a certain way upon the peripheral optic filaments. It also protects the nerve filaments from all contact with external conditions, except light.

What is the only stimulus which ordinarily excites the optic nerve?

Light.

What is the purpose of the movements of the eyeball?

In order that objects may be brought within the range of vision without movements of the head.

If electrical, mechanical, or other stimuli be applied to the optic nerve, what sensations will they produce?

Light is the only thing appreciated.

What is the function of the sclerotic coat of the eye?

It gives shape and protection to the organ.

Is the sclerotic coat continuous all over the eyeball?

No, it is not; for at the anterior portion is a window-like opening, known as the *cornea*, through which the rays of light pass.

What is the function of the cornea?

It permits light to enter the eye in much the same manner as a window-pane lets light into a room, and it also effects very markedly refraction of the rays of light.

What peculiar bodies have we in the cornea which move about?

The corneal corpuscles, which resemble amœbæ in their movements.

Does the cornea possess nerves and bloodvessels?

Only nerves, which are partly sensory in function.

In what way, then, is it nourished?

By absorption from the bloodvessels at the corneal margin.

What is the function of the choroid root?

Owing to its black, pigmented connective tissue cells, it prevents the transmission of all light from the exterior, save by the corneal opening, and prevents reflections from side to side. It is this coat which lacks pigment in albinoes and nocturnal animals, and its absence prevents good vision in the daytime.

What are the ciliary processes?

They are highly vascular folds of the choroid, occurring near the edge of the cornea.

What is the function of the ciliary muscle?

It attaches the choroid to the sclerotic coat, and governs the diameter and shape of the crystalline lens.

What is the function of the iris?

It is a circular membranous diaphragm provided with a central aperture, the pupil, and regulates the amount of light entering the eye. It contains two sets of muscular fibres, circular and radiating.

What are the functions of these two sets of muscular fibres?

The radiating fibres dilate the pupil, the circular fibres contract it.

What is the object of this pupillary movement?

The regulation of the amount of light entering the eye.

What arrangement have we on the posterior surface of the iris to prevent the transmission of light through it?

A layer of dark pigment.

What is the nerve supply of the circular fibres of the iris?

The oculo-motor.

What is the nerve supply of radiating or dilating fibres?

The trifacial and sympathetic.

Why does the pupil contract when we are looking at near objects, but dilate for objects which are far away?

When an object is near the rays of light are so near together that they enter through a small opening; when it is far off the pupil dilates, in order to let all the rays in that it can to make the image more distinct.

What is the function of the retina?

Lying next to the choroid coat the retina is formed by the expansion of the optic nerve, and it is this membrane which receives the impression of light.

In what way do the nerve filaments end in the retina?

In the rods and cones.

Which of these is most highly developed in man?

The rods.

What do you mean by the blind spot?

A small point in the retina on which, when light falls, no impulse is produced; it is the point of entrance of the optic nerve.

What do you mean by the macula lutea?

The point at which rays of light produce the greatest visual impression. It is exactly in the centre of the retina.

Are the rods or the cones in greater number here?

The cones.

What is the visual purple?

A certain purple substance on the retina, which is destroyed by contact with light. It has been supposed that it aids vision, but this is apparently contradicted by the fact that it is absent from the cones and the macula lutea, where vision is best. It can only be seen by opening an eye in a dark room, and flashing a light upon it. If the operation be quickly done the image falling on the retinal pigment may be made permanent by dipping it quickly in a strong solution of alum.

Does every part of the retina receive all the rays of light?

No. Each portion receives different colored rays. The peripheral portion sees the red rays, etc.

What is the function of the aqueous humor of the eye?

It affords a medium in which the iris can move. It also supports the posterior surface of the cornea, and influences the refraction of light.

What is the function of the vitreous humor?

It fills out the eyeball and keeps it tense, and aids very largely in the refraction of the rays of light transmitted to it through the crystalline lens.

What is the function of the crystalline lens?

It acts like a strong, magnifying glass, and is biconvex. It is the most important refracting portion of the eye, and, aided by other portions of the optical apparatus, directs the rays of light in such a manner that they fall properly on the retina. It also separates the aqueous from the vitreous humor.

In what way are images thrown on the retina?

They are inverted by the lens, which is biconvex.

Why do we not see objects, therefore, upside down?

Because the brain interprets the inverted image for one in the proper position.

What variation is there in the power of refraction of the various parts of the lens?

It increases in power of refraction from without inward.

Give the essential portions of the eye for the carrying out of its functions, namely, sight.

1. A retina or nervous mass to receive and transmit impulses.

2. Certain refracting media so arranged as to throw the rays of light in proper form.

3. A contractile diaphragm, the iris, which governs quantity of light admitted.

4. A contractile muscle, the ciliary muscle, to regulate the shape of the lens and to "accommodate" the eye to distances.

What would be the effect if the retina was exposed to the light with no refracting media in front of it?

The perception of light from darkness, but no objects could be seen.

What do you mean by the term "accommodation of the eye?"

The function of the eye by which we are enabled to see objects at various distances.

The rays of light for good sight must be transmitted from an object and focussed at a given point on the retina. If the focus occurs in front or behind the retina instead of on it, the vision is indistinct. The lens, however, in the normal eye varies in its biconvexity to such an extent that it collects the rays, be they far apart or near together, and in every instance focusses them directly on the retina.

What do you mean by the "near point?"

The "near point" is the nearest point at which the eye can clearly perceive an object held before it, as, for example, printed matter held close to the face.

The "far point" is the same thing reversed, save that the far point in the human eye is an infinite distance.

By what means do we judge of distance?

This is largely a matter of education and is unconsciously ob-

tained, in the same way as the judgment of size, a mere matter of practice.

What is chromatic aberration?

It is the breaking up of ordinary white light into colored rays, owing to the different colored lights of which ordinary light is made up. It is due to a defect in the optical apparatus, but in the normal eye it is diminished by the iris, which cuts off the marginal rays.

What is spherical aberration?

It depends upon the fact that luminous rays passing through a convex lens strike the various parts of the surface at different angles, and, hence are differently refracted, the rays striking the margin of the lens being more bent than those passing through the centre. Spherical aberration does not, however, cause inconvenience, since the iris allows only the central rays to pass.

What is astigmatism?

It consists in an inability to see clearly lines running at certain angles.

It depends either upon some irregularity in the shape of the cornea, or in the shape of the lens.

What are entopic images?

Those which depend on the presence of some opacity in the transparent media of the eye itself. They occur in all eyes to a a certain extent, and are frequently noticed when one uses the microscope.

What is the cause of color-blindness?

The inability of certain areas of the retina to perceive those rays of light which normally fall on them, owing to the imperfect development of these areas. The common forms of blindness are for the red, green, and yellow rays.

What is diplopia?

Double vision, due to the fact that each eye receives the impulse at a different time from the other.

What is hemianopsia?

Blindness of one-half of the eye so that objects are split down the middle and only half of the body perceived. Since the rays of light cross in the eye, the part of the retina which is blind is always opposite the object, which cannot be seen. Thus, when the eye sees no objects to the left of it, it is the right side of the eye which is blind.

What is myopia?

"Short sightedness." A condition of the eye in which objects are focussed at a point in front of the retina.

What is hypermetropia?

"Far sightedness." A condition of the eye in which objects are focussed behind the retina.

What do you mean by presbyopia?

A state common to old age, due to loss of the power of accommodation.

What is an emmetropic eye?

A normal eye.

Does such an eye as an absolutely normal eye exist?

Probably not, or in very rare instances.

By what form of glass would you remedy myopia?

By a concave glass.

By what form of glass would you relieve hypermetropia?

By a convex glass.

Why do you do this?

Because in the myopic eye the lens is too convex, while in the hypermetropic eye it is not convex enough.

What do you mean by dioptric media?

Transparent bodies which so refract the light that images come to a focus on the retina.

Hearing.

In the same way that all impulses travelling along the optic nerve are interpreted as light, so are all the impulses travelling along the auditory nerve interpreted as sound.

Through how many divisions of the ear does the sound pass?

Three, the external ear and auditory canal, the middle ear, which is shut off from the auditory canal by the tympanic membrane, and the labyrinth.

What is the purpose of the external ear?

To collect sound.

What is the function of the auditory canal?

By circumscribing the air it increases its vibrations.

What is the function of the cerumen of the external ear?

To catch foreign bodies which might otherwise enter.

What is the function of the tympanic membrane?

It receives the vibrations of the air in the auditory canal, transmitting them to the bones of the middle ear.

For what purpose is the tympanic membrane sloped from outward inward?

If it were directly across the canal it would not be of great enough extent.

By what means are the vibrations of sound transmitted after leaving the tympanic membrane?

Three small bones known as the malleus, incus, and stapes join together, and reach from the membrane to a secondary membrane which covers the oval window leading into the vestibule of the internal ear; the malleus is attached to the tympanic membrane, while the stapes is in contact with the oval window.

What is the function of the stapedius muscle?

It is attached to the stapes, and when it contracts pulls that bone away from the oval window, otherwise a loud sound might jam the bone into the oval window and produce deafness.

What is the function of the tensor tympani muscle?

By drawing the handle of the malleus internally it increases the intensity of the tympanic membrane and prevents it from vibrating too much to sounds of great intensity.

What is the function of the laxator tympani muscle?

It draws the handle of the malleus outward, and relaxes the tympanic membrane.

What is the function of the Eustachian tube?

It communicates with the pharynx and opens into the middle ear back of the tympanic membrane, affording vent by which, when the drum is driven in, some of the air may escape. It equalizes the pressure within and without.

Is the Eustachian tube constantly open?

No, it is not; if it were, the various sounds in the mouth would produce sounds in the ear.

In what way is sound transmitted, after passing through the ossicles, to the terminal filaments of the auditory nerve?

Through the semicircular canals and the spiral staircase.

What fills the semicircular canals?

A liquid known as the endolymph.

In what manner does the endolymph receive impulses from the exterior?

The endolymph is in direct contact with the membrane which covers the oval window, and when the stapes strikes against this membrane it produces vibrations which are taken up by the endolymph.

In what way do the nerves end in the semicircular canals?

In peculiar epithelioid cells, to which are attached fine hair-like processes.

What are the functions of the otoliths?

These small calcareous masses are set in motion by the vibra-

tions of the endolymph and come in contact with the endings of the nerves, producing impulses. The function of those nerve fibres which run to the cochlea is not clearly understood.

What function have the semicircular canals other than hearing?

They appear to govern equilibrium, for if injured the animal immediately loses its balance. When the horizontal canal is divided the animal rolls its head from side to side. When one of the vertical canals is cut the head moves up and down.

What is the function of the organ of Corti?

It is not distinctly known, but it was supposed to be especially developed in persons with musical tendencies, till it was found that the pig possessed them in a highly developed state. As nerve filaments end in these rods, it has been supposed that each set of rods responds to a certain set of notes.

What differences in sound can the ear distinguish?

Loudness, pitch, and quality. The judging of the distance from which a sound is transmitted is purely a matter of training.

The Voice and Speech.

With scarcely any exception all air-breathing vertebrates possess some arrangement for the production of sound in some part of the respiratory apparatus. In some animals various modifications of this sound are produced. In man its modifications are so great as to permit of speech.

In what way is the voice or sound produced?

By an expiratory blast of air being forced through the narrow opening at the top of the windpipe, called the glottis. The glottis, it will be remembered, lies in the lower part of the larynx and is bounded on each side by thin membranous bands, which, extending from side to side, vibrate as the air rushes over them. For this reason, opening of the trachea prevents speech, since all the air rushes out of the opening rather than over the cords.

What are the chief organs of the voice?

The vocal cords. These are governed by the muscles of the larynx.[1]

What is the function of the larynx?

It acts as a cavity in which the vocal cords may produce the voice.

What is the function of the thyroid and cricoid cartilages?

The function of these two cartilages is chiefly for the purpose of affording stiff walls around the vocal apparatus for the sake of protection and attachment. The thyroid cartilage forms an incomplete ring around the larynx, and covers only the front portion and sides. The cricoid cartilage, on the other hand, is a complete ring, the back part of the ring being broader than the front.

What is the function of the arytenoid cartilages?

They are situated on the top of the back portion of the cricoid cartilage and are movable upon it, forming a place for the insertion of certain muscles concerned in speech.

What are the intrinsic muscles of the larynx?

They are those which have a direct action on the vocal cord, and are nine in number—four pairs and a single muscle: two crico-thyroids, two thyro-arytenoids, two posterior crico-arytenoids, two lateral crico-arytenoids, and one arytenoid muscle.

What are the functions of these muscles?

When the crico-thyroids contract they rotate the cricoid on the thyroid cartilage in such a manner that the upper and back part of the former, and of necessity the arytenoid cartilages on the top of the cricoid cartilage, are tipped backward, while the thyroid is inclined forward. The result of this is that the vocal cords being attached in front to the thyroid cartilage and posteriorly to the cricoid cartilage are put on the stretch. The thyro-arytenoid muscles have an opposite action, for they pull the thyroid backward and the arytenoid and the upper and back part of the cricoid

[1] For the anatomy of the larynx and those portions of the body concerned in speech, see an anatomical text-book.

cartilages forward, thus relaxing the vocal cords. The posterior crico-arytenoids dilate the glottis and separate the vocal cords by an action on the arytenoid cartilage. When they contract they pull together the outer angles of the arytenoid cartilages in such a manner as to rotate the latter at their joint with the cricoid, and to throw asunder their anterior angles to which the vocal cords are attached.

What muscles oppose these posterior crico-arytenoid muscles?

The lateral crico-arytenoids, which, pulling in the opposite direction from the other side of the axis of rotation, have, of course, exactly the opposite effect, and enclose the glottis. The arytenoid muscle may also close the glottis almost completely, by pulling together the upper parts of the arytenoid cartilages, between which it extends.

What is the nervous mechanism of the voice?

The sensory filaments in the pneumogastric give the glottis that acute sensibility which prevents the ingress of foreign bodies or noxious gases into the air-passages. The superior laryngeal branch of the vagus and the inferior laryngeal branch, or the recurrent nerve, coöperate not only with the pneumogastric in the closure of the glottis which excludes foreign bodies, but also in the protection and regulation of the voice. The inferior laryngeal nerve governs the contraction of the muscles that vary the tension of the vocal cords, while the superior laryngeal conveys to the mind the sensations of the state of these muscles, which is absolutely necessary for their intelligent guidance.

What three properties are possessed by the human voice?

Quality, pitch, and intensity.

Over how wide a musical range does the human voice extend?

Including all forms of voice, about three and one-half octaves; but of this wide range a single individual can rarely sing more than two octaves.

What difference exists between the notes of the female voice and those of the male?

The lowest note of the female voice is about an octave higher than the lowest note of the male voice. The highest note of the female voice is about an octave higher than the highest note of the male.

In what portion of the vocal apparatus is the variation in sound produced which results in speech?

Not in the larynx, but in the mouth and nose, by means of the teeth, tongue, and lips.

What sound do we have when speech is not accompanied by the action of the vocal cords?

Only a whisper.

What effect upon sound has approximation of the vocal cords?

The sound emitted is high pitched in character, while non-approximation of the cords produces sound of greater volume, but of lower pitch. The pitch does not depend, however, absolutely on the approximation or non-approximation of the cords, but more upon the tensity of the cords themselves.

What is the function of the epiglottis in regard to sound?

When pressed down so as to cover the cavity of the larynx it serves to render the notes deeper in tone, and, at the same time, somewhat fuller in quality.

The Sympathetic Nerve.

It will be remembered that the sympathetic system contains a very large number of non-medullated nerve fibres, and consists of a double gangliated prevertebral cord, one on each side of the vertebral column.

What are the rami communicantes?

The nerves given off by the spinal nerves to the sympathetic cord. Each spinal nerve does this.

What do you mean by the cephalic, dorsal, and abdominal portions of the sympathetic?

Those portions which govern these areas. In the head the cephalic portion anastomoses with the cranial nerves to a great extent. The abdominal portion supplies the abdominal organs.

What are the functions of the sympathetic?

First, the *independent* functions as represented by the automatic cardiac ganglia, the mesenteric plexus of the intestine, and the plexuses of the uterus, Fallopian tubes, ureters, and lymph and bloodvessels. They are independent in that they are capable of acting without any impulses from higher centres, but they may also be governed by the spinal centres under some circumstances. *Second*, the *dependent* functions which are governed by centres, as, for example, the sensory fibres of the splanchnics.

What is the function of the cervical sympathetic?

It contains (1) pupil-dilating fibres which, according to Budge, arise from the spinal cord and run through the upper two dorsal and lowest cervical nerves into the cervical sympathetic, which conveys them to the head.

What does the cervical sympathetic also supply?

(2) *Motor* fibres for Müller's smooth muscle of the orbit, and *partly* for the external rectus muscle of the eye. It also supplies (3) *vaso-motor* branches for the outer ear and the side of the face, tympanum, iris, choroid, retina in part, the œsophagus, larynx, thyroid gland, and fibres for the vessels of the brain and its membranes; (4) *secretory* and vaso-motor fibres for the salivary glands. (5) Sweat secretory fibres are given off, as are also secretory fibres to the (6) *lachrymal* glands, according to Wolferz and Demtschenko.

What are the functions of the thoracic and abdominal sympathetic?

(1) The sympathetic portion of the cardiac plexus, which receives *accelerating* fibres for the heart from the lower cervical and first thoracic ganglion. (2) The cervical sympathetic and the splanchnics contain fibres which, when their central ends are stimulated, excite the cardio-inhibitory centre in the medulla.

Give an example of this.

If an animal be struck sharply on the belly, over the solar plexus, death may result from cardiac stoppage due to reflex inhibition.

What is the splanchnic?

The splanchnic is a division of the sympathetic, and contains vaso-motor filaments. All the vaso-motor nerves do not run through the cord, but some of them leave the cord high up and pass into the sympathetic. These nerve filaments in the splanchnics govern the bloodvessels of the abdomen very largely. The splanchnic also contains vaso-motor fibres which supply the kidneys.

What effect has section of the cervical sympathetic, or its rami communicantes, on the pupil?

It causes contraction of the pupil.

What other effect has section of the cervical sympathetic?

It causes increased fulness of the bloodvessels on that side, the eyelids are not held well apart, while the eyeball is sunken and retracted. Sometimes unilateral atrophy of the face comes on. If this section be performed in young growing animals, hypertrophy of that ear and side of face occurs, owing to the increased blood supply and other trophic changes.

What is the effect of stimulation of the cervical sympathetic?

It causes dilatation of the pupil, and occasionally hyperidrosis or profuse sweating of that side of the head. There is also protrusion of the eyeball, and the eyelids are held wide open. The eyeball, instead of being sunken, as after section, is in a condition of exophthalmos.

GENERATION AND DEVELOPMENT.

What do you mean by generation and development?

The first term signifies the original cause of growth, while the second term signifies the manner of growth after it is once begun.

Generative Organs of the Female.

They consist of two ovaries, two Fallopian tubes or oviducts, the uterus, and a canal known as the vagina.

What is the function of the ovaries?

The formation of the ova or eggs.

What is the function of the Fallopian tubes or oviducts?

The conduction of the ova from the ovaries to the uterus.

What is the function of the uterus?

It is a cavity in which, if impregnated, the ovum is retained until it is fully developed and capable of maintaining its life independent of the parent.

What is the function of the vagina?

It is the canal which receives the male generative organ, the penis, in the act of copulation, and is the passage through which the fœtus is discharged.

Describe the ovaries.

They are two oval bodies situated in the cavity of the pelvis, one on each side, inclosed in the folds of the broad ligaments. Each ovary measures about an inch and a half in length and three-quarters of an inch in width. They are about half an inch in thickness, and are attached to the uterus by a narrow fibrous cord, the ligament of the ovary, and move slightly to one of the fimbriæ of the Fallopian tubes. They are enveloped by a dense fibrous tissue. They are covered on the exterior by the *germ epithelium*. The inner substance, or stroma, is a soft fibrous tissue containing, imbedded in it, a number of vesicles in various stages of development.

What are these vesicles called?

Graafian vesicles.

In what way do the Fallopian tubes grasp the ovule when it is expelled from the ovary?

By means of their fimbriated extremities, which are in constant ciliary movement.

Describe the formation of the ovule in the ovary.

The vesicles in the stroma gradually approach the surface until they project above it. Each follicle or vesicle is covered by an external membranous envelope lined with a layer of nucleated cells, the *membrana granulosa*. This follicle contains liquid full of small microscopic bodies, with the ovule nearly in its centre, unless the follicle is fully matured when it comes in contact with the *membrana granulosa*.

What is the discus proligerus?

A granular zone of the nucleated cells of the membrana granulosa, which is heaped around about the ovule.

What is the size of the human ovule?

About $\frac{1}{120}$th of an inch.

What is the zona pellucida or vitelline membrane?

The investment of the ovule, and it adheres closely to the discus proligerus.

What lies within the zona pellucida?

The yelk or vitellus, which is composed of granules and globules of various sizes.

What arrangement have these globules?

The largest are at the periphery, the smallest are at the centre.

What does the yelk or vitellus contain?

The *germinal vesicle* or the vesicula germinativa.

What does this germinal vesicle contain?

At its periphery, at the point nearest the yelk, it contains the *germinal spot* or the *macula germinativa*.

These are all the parts of the *Graafian* follicle.

Does the formation of Graafian follicles go on constantly during the child-bearing part of life?

Yes.

What do you mean by the discharge of the ovule?

When the follicle is ripe and has reached the surface of the ovary, the follicular wall becomes thinner and finally bursts. The ovule and its fluid surroundings escape on the surface of the ovary, which is grasped by the Fallopian tube, down which the ovule travels.

Is there any difference in the periodicity of the maturity of the ovule in the different varieties of animals?

Yes; in human beings it is once in every twenty-eight days, while in the common fowl it is constant.

What is the difference between the ovule and the ovum?

The term ovule is ordinarily applied to the egg previous to impregnation, while the ovum is the fecundated ovule.

What is menstruation?

It is regarded by most physiologists as the flow of blood accompanying the discharge of a ripened ovule. The rupture of a follicle is not necessarily accompanied by menstruation, neither is menstruation necessarily followed by ovulation.

Does rupture of the follicle take place before or after the flow?

In most cases before or at the beginning; more rarely at the middle or end of menstruation.

Describe the menstrual discharge.

It is a thin, sanguinolent fluid having a peculiar odor, and consists of blood, epithelium, the mucus of the uterus and vagina, and the remains of the mucous membrane lining the uterus.

What is this mucous membrane called?

The *decidua menstrualis*, which is developed to perfection just before the menstrual flow and then thrown off.

Can menstruation be regarded as a hemorrhage?

No; it can not. It is merely a destructive process whereby the membrane which was prepared for receiving a fecundated ovule is thrown off.

At what time of life does menstruation begin and end in the temperate zone?

It begins at twelve or fourteen years of age, and ceases at a period between forty and fifty.

Does menstruation ever occur during pregnancy, or in nursing women?

Rarely; but such cases are on record.

What is the corpus luteum?

At the time of rupture of the Graafian vesicle, a yellowish mass, the *corpus luteum*, develops itself. It is a round, solid body whose walls, after the rupture, become covered by small buds of flesh-like matter, resembling a granulating wound, and these granulations extend above the ovarian surface. Ultimately they become covered, but still go on growing inside the ovary. As pregnancy goes on, the red granulations change to yellow and its consistence becomes firmer.

Does the corpus luteum depend for its formation on the effusion of blood which takes place when the follicle ruptures?

Not in the least. *Remember this.* The corpus luteum is, in reality, a growth of cells from the *membrana granulosa.*

What difference is there in the growth of the corpus luteum of pregnancy and in that of ordinary menstruation?

In pregnancy it remains till gestation is nearly ended. When impregnation does not occur it shortly disappears.

The Male Sexual Organs.

What is the function of the testicles?

They are the organs which secrete portions of the semen.

What other tissues aid in this secretion?

The vesiculæ seminales, the prostate gland, and Cowper's glands.

What does the semen consist of?

Of the secretion of all these tissues.

In what way is the secreting portion of the testicle arranged?

Into two parts, one of which is the body of the testicle inclosed within a tough, fibrous membrane, the *tunica albuginea*, which is covered externally by a serous membrane, the *tunica vaginalis*. The second part is the *epididymis* and *vas deferens*.

What is the vas deferens, and what is its function?

It is the duct of the testicle, about two feet in length. It passes to the lower part of the epididymis, with which it is continuous, where it becomes exceedingly tortuous in its course.

Of what does the epididymis consist?

Of a single tube about twenty feet long.

What are the tubuli seminiferi?

They make up the parenchyma of the organ.

In what way, and from what are the spermatozoids formed?

The seminal tubule is limited by an elastic membrane, the *membrana propria*, inside of which are several layers of cells, known as the *seminal cells*.

How many kinds of seminal cells have we?

Two. Those resting quietly, others in a state of active division. The active cells are called the mother cells; and the smaller cells, resulting from their division, the daughter cells or *spermatoblasts*. The spermatozoids are formed from the spermatoblasts.

What is the appearance of the spermatozoid?

It consists of a small body or head, to which is attached a cilium, or rapidly moving tail.

What is the function of the spermatozoids?

They are absolutely needful for impregnation, and it is the spermatozoids which fecundate the ovule.

How does the semen reach the exterior of the body?

It is secreted in the tubules of the testicles, then passes along the vasa deferentia into the vesiculæ seminales, and from there into the urethra.

What is the function of the seminal vesicles other than the carrying off of the semen?

They secrete some of the liquid in which the spermatozoids float or swim. This is probably their chief function, at least in some animals.

What is the function of the prostate and Cowper's glands?

To add the proper liquid to the semen.

Of what, therefore, does semen consist?

The liquor seminis and the spermatozoids, with detached epithelial cells.

Development.

In what part of the female genital organs does the ovule become fecundated?

Most commonly in the upper part of the Fallopian tube.

What changes take place in the ovum or the fecundated ovule?

The visible change is a slight amœboid movement of the protoplasm of the ovum, which is shortly followed by segmentation, which consists in the repeated subdivision of the cells present.

How long does this segmentation last?

It is finished by the time the ovum reaches the uterus.

What is seen in the centre of each segment?

A central vesicle, which is the result of the repeated division of another central vesicle, just as the segments themselves are the result of the division of the yelk itself.

What appearance has the ovum as it enters the uterus?

Owing to the many segmentations, it is granular, and resembles a mulberry.

How long a time does the passage of the ovum from the ovary to the uterus take?

Probably eight or ten days.

What is the germinal or blastodermic membrane?

It is a membrane which is formed by the accumulation at the periphery of the yelk of a number of the segments or cells. Owing to their number they are pressed against one another, and become polyhedral in shape.

What are the layers of the blastoderm?

The epiblast, mesoblast, and hypoblast.

What is the function of the epiblast?

From the epiblast are eventually developed the epidermis and its various appendages, the cerebro-spinal *nerve centres*, the sensory epithelium of the mouth, and the salivary glands.

What are developed from the hypoblast?

The epithelum of the whole digestive canal, and the lining of all the ducts which open into it; the parenchyma of the liver and pancreas, and the epithelium of the respiratory tract.

What are developed from the mesoblast?

All the organs not so far mentioned, all the connective tissues, the muscles, the vascular and genito-urinary apparatus, and the entire digestive tract, save its lining epithelium.

What is the germinal area?

The position at which the embryo is about to appear. It is at first circular, then pyriform.

What is the area pellucida?

A clear, transparent spot, which develops in the centre of the germinal area.

What is the area opaca?

That portion of the germinal area surrounding the area pellucida.

What is the primitive groove?

A shallow longitudinal groove which is the first trace of the embryo. It appears near the back part of the area pellucida.

What is the medullary groove?

A more permanent groove which soon replaces the primitive groove. It begins at the anterior part of the area pellucida, and gradually displaces the primitive groove.

What are the laminæ dorsales?

Two longitudinal elevations which bound the medullary canal. They are folds of the epiblast which grow up and extend over and join each other over the medullary canal, forming it into a closed canal or tube.

What is this tube now called?

The primitive cerebro-spinal axis.

At what portion of the embryo do the laminæ dorsales first unite?

About the neck, then the head, and down to the lower extremity.

What is the notochord or chorda dosalis?

It is an aggregation of cells from the mesoblast immediately underneath or back of the medullary canal. It extends nearly the whole length of the canal, and occupies the future position of the vertebræ.

What are the protovertebræ?

Square segments composed of cells from the mesoblast which appear on each side of the medullary canal along its whole length.

What is the "splitting of the mesoblast"?

Outside of the protovertebræ the mesoblastic cells are split up into two laminæ, known as the *parietal* and *visceral*. These laminæ form the origin for the walls of the trunk. The parietal lamina is closely connected with the epiblast which adheres closely to the

hypoblast, and forms the serous and muscular walls of the alimentary canal and other parts.

What is the somatopleure?

The united parietal lamina and the epiblast.

What is the splanchnopleure?

The united visceral layer and the hypoblast.

What eventually becomes of the space between the somatopleure and the splanchnopleure?

It forms the pericardium, pleuræ, and peritoneum.

What are the head and tail folds?

Those folds of the blastoderm which limit the embryo at the head and caudal extremities. Similar folds or depressions mark off the lateral margins of the embryo, which now finds itself entirely separate from the yelk and surrounded by a clear space.

What is the last portion of the embryo to become completely separated from the yelk?

The head and caudal extremity are first separated, but the anterior wall of the belly is not closed by the folds till later. Indeed it is never closed in fœtal life, for the *umbilicus* is the remains of this connection with the yelk.

What is the neural cavity?

That cavity formed by the upward growth of the laminæ dorsales.

What is the body cavity?

That cavity formed by the downwardly folded blastoderm.

What are the visceral plates?

The downwardly folded portions of the blastoderm are known as the visceral plates.

What forms the rudiment of the alimentary canal?

The folding in of the splanchnopleure lined by hypoblast pinches off a portion of the yelk-sac inclosing it in the body cavity.

What is the condition of this rudimentary alimentary canal?

It is blind or closed at both ends at this time, while its centre communicates freely with the cavity of the yelk-sac.

What is the canal called which permits of this communication?

The vitelline or omphalo-mesenteric duct. This condition divides the yelk-sac into two portions.

What is the portion of the yelk-sac outside the body cavity called?

The *umbilical vesicle.*

What is the purpose of the umbilical vesicle?

It affords nutriment for the embryo.

In what way does the nutriment reach the embryo?

Through the omphalo-mesenteric vessels which ramify in the walls of the yelk-sac.

Does this yelk-sac or umbilical vesicle afford food all through pregnancy for the embryo?

In mammalia it lasts only for a short time, the nourishment being derived from the mother.

What is the amnion?

Beyond the head and tail folds the somatopleure, coated by epiblast, rises in folds which grow up and arch over the embryo, anteriorly, posteriorly, and laterally, all directed toward one point over the dorsal surface of the embryo.

What is the true amnion?

The inner of the two layers of the somatopleure forms the true amnion.

What is the false amnion?

The outer layer of the somatopleure.

What is the chorion?

It is formed by the coalescing of the inner surface of the original vitelline membrane with the false amnion.

How is the amniotic cavity formed?

The cavity between the true amnion and the external surface of the embryo becomes a closed space, which is called the amniotic cavity.

Does the amnion adhere closely to the embryo?

No, it gradually is distended with fluid which separates it from the embryo.

What is this fluid called, and what is its function?

The *liquor amnii*, which increases as pregnancy goes on. This forms a yielding cushion-like support for the embryo, protecting it from injury and gradually distends the neck of the uterus in parturition.

What is the allantois?

It is a highly vascular growth, arising from the hinder portion of the peritoneal cavity, which gradually pushes its way out through the amniotic folds, attaching itself to the outer layer of the amnion (false amnion). In other words, it becomes attached to the chorion, in mammals in one spot, in birds all over the chorion.

What is formed at this point?

By the interlacing of these vessels with those of the mother the *placenta* is developed.

Of what does the chorion now consist?

Three layers: 1st, the vitelline membrane; 2d, the outer layer of the amniotic fold; 3d, the allantois.

What are the villi of the chorion?

Small processes on its surface which soon become vascular, particularly so in the region of the future placenta, so as to dip between the maternal vessels.

What changes take place in the uterine mucous membrane during this time?

The follicles become tortuous and enlarged, while the epithelial layers increase in amount.

What is the result of this increase in the uterine mucous membrane?

It makes up the membrana decidua.

Into how many divisions are the portions of the membrana decidua divided?

Three: The *decidua vera, decidua reflexa,* and the *decidua serotina.*

What is the function of these three divisions?

The *vera* lines the cavity of the uterus; the *reflexa* grows up around the ovum and forms an investment for it; while the *serotina* becomes especially developed in connection with the villi of the chorion. *Remember,* by the third month the *vera* and *reflexa* come in contact, and can no longer be distinguished one from the other.

What is the function of the placenta?

It is an organ by which the gaseous and nutritive changes take place between the maternal tissues and the embryo.

The placenta has, therefore, a fœtal part and a maternal part.

THE DEVELOPMENT OF ORGANS.

Vertebral Column and Cranium.

How are the vertebral column and cranium developed?

The notochord or chorda dorsalis consists primarily of soft cellular cartilage which is gradually inclosed in a membranous sheath, which after a time becomes fibrous and has transverse annular fibres. The protovertebræ (see page 154) send processes downward and inward to surround the notochord, and also upward between the medullary canal and the epiblast covering it. In the former situation the cartilaginous bodies of the vertebræ make their appearance, in the latter their arches which inclose the neural canal. The vertebræ do not exactly correspond in their position with the protovertebræ, but each permanent vertebra is developed from the contiguous halves of the protovertebræ.

The cranium is developed from a prolongation of the vertebral

column, and is formed long before the facial bones. It is formed of one mass, the cerebral capsule, the chorda dorsalis being continued into its base and ending there with a tapering point.

In what way is the dorsal portion of the body formed?

The muscles and integument of the back, with the exception of the epiderm, which is developed from the epiblast, are developed from the *musculo-cutaneous* plate which is formed by the dorsal portion of the protovertebræ.

What is developed from the ventral portion of the protovertebræ?

They give rise to the vertebræ and the heads of the ribs, but the outer part of each protovertebra gives rise to a spinal ganglion and nerve-root.

What is the condition at this time of the chorda?

It is inclosed in a case, formed by the bodies of the vertebræ, and gradually wastes and disappears.

How are the body cavities formed?

The *dorsal laminæ* coalesce at the back and complete, by their union, the spinal canal, and the visceral laminæ coalesce anteriorly and thus form the thoracic and abdominal cavities. An analogous process occurs in the facial and cervical regions, but the inclosing laminæ are cleft. When these clefts fail to unite in the median line cleft-palate or harelip results.

Extremities.

In what way are the extremities developed?

They appear in the form of leaf-like elevations from the parietes of the trunk at points where more or less of an arch will be produced for them within.

Heart and Bloodvessels.

How is the heart developed?

It makes its first appearance as a solid mass of cells of the splanchnopleure. A cavity is hollowed out of the centre, and

those detached cells float about in a liquid which soon begins to move about under the pulsations of the embryonic heart.

How are the bloodvessels developed?

In the formation of the large vessels masses of embryonic cells are arranged in longitudinal form and hollowed out in much the same manner as the heart, the cells of the heart cavity and blood-vessel cavities forming corpuscles. The capillaries seem to be formed of cells arranged end to end in single line and hollowed like a pipe-stem.

Nervous System.

How is the nervous system developed?

All the *spinal nerves* are derived from the mesoblast, as are also the cranial nerves, except the optic and olfactory, which are outgrowths of the anterior cerebral vesicles. The sympathetic system is also developed from the same mesoblastic layer.

Have the spinal cord and brain the same origin as the spinal nerves?

Yes. They arise from the epiblast for the gray matter, and for the white matter.

From what is the spinal cord developed?

Out of the primitive medullary tube, which results from the folding in of the dorsal laminæ.

How is the gray matter formed?

The tube is narrowed in one diameter so that the canal becomes narrow and oval in shape, and finally the two opposite sides unite in the centre of the slit, while the attachments of the two sides at the top and bottom of the canal decrease in thickness, and finally separate. The white matter is derived from the surrounding mesoblast and grows up around the gray columns. The fissures are formed by the separating at the top and bottom of the tube already described.

What do you mean by the cerebral vesicles?

A widening out of the medullary canal very early in embryonic life.

How many cerebral vesicles have we?

Three.

What is the purpose of each?

From the first anterior vesicle are budded off the two primary optic vesicles, and the rudiments of the hemispheres appear in the form of two outgrowths at a higher level. The middle vesicle gives off the rudiments of the corpora quadrigemina, the crura cerebri, and the aqueduct of Sylvius. The posterior vesicle gives off the rudiments of the cerebellum, pons Varolii, the medulla oblongata, and auditory nerve.

Eye.

From what is the eye developed?

The anterior cerebral vesicle, which sends out a smaller vesicle on each side, the primary optic vesicles, which are hollow. The stalks which attach the vesicles to the original vesicle form the optic nerves. After this the formation of the *lens* and *optic cups*, or secondary optic vesicles, begins.

How is the lens formed?

By a thickening of the epiblast, which indents the extremity of the primary optic vesicle and pushes it back till the front wall of the vesicle is in contact with the posterior wall, and the optic cup is thereby obliterated.

What does this front wall, which has been pushed back, form?

The retina.

What does the back wall form?

The pigment layer of the choroid.

The margins of the cups grow up around the lens everywhere except at the lower part, by the optic nerve, where a fissure remains.

What is this fissure called?

The *choroidal fissure*.

What is its purpose?

Through it the mesoblast, which forms the connective tissue of the eye, finds an entrance into the cavity of the eye.

Ear.

How is the ear developed?

Early in embryonic life a depression occurs on each side of the surface of the head, which is covered by a membrane, the *primary otic vesicle.*

What is the purpose of this vesicle?

It develops the membranous labyrinth of the internal ear. The surrounding mesoblast gives rise to the various bony and cartilaginous parts inclosing the membranous labyrinth, the bony semicircular canals, etc. The mesoblast also develops the auditory nerve.

Nose.

How is the nose developed?

It originates, like the eyes and ears, in a depression of the superficial epiblast at each side of the fronto-nasal process, and these cavities gradually grow back till they reach the cavity of the mouth.

Alimentary Canal and Organs.

In what way is the alimentary canal developed?

It results from the folding in of the splanchnopleure, and is at first straight and parallel to the vertebral column. It is connected with the omphalo-mesaraic duct, a point which corresponds with the lower segment of the ileum, but the duct atrophies and usually disappears about the fourth month. The attachment is at first very broad, and only a thin stratum of mesoblast separates the hypoblast of the canal from the notochord and protovertebræ; but it subsequently attenuates and becomes the mesentery. In the fourth month the part connected with the umbilical vesicle loops forward. The part above the umbilical opening becomes the

small intestine, and the part below almost wholly the large intestine. The limit between the two is soon indicated by a projection, the cæcum. The intestine separates from the abdominal wall, the remains of the attachment appearing at the third month, and sometimes later, as a thread-like appendage to the lower part of the ileum. Convolutions then begin to form, and an enlargement in the region of the liver, which is the stomach.

In what way is the posterior opening in the intestine formed?

By the establishment of a communication between the cloaca, or tube common to the gut and allantois, and a depression outside of the body at about the sixth or seventh week. At the same time a septum, which is the future perineum, separates the intestine from the organs forming the allantois. The mouth is formed in the same manner.

In what way are the salivary glands, the pancreas, and the liver developed?

The liver commences as a projection formed by two primitive hepatic ducts, which divide and subdivide. At the periphery of the ducts are solid masses of cells which proceed from the hypoblast. The mass of the gland is developed from the mesoblast. The liver secretes as early as the third month. The pancreas is also formed from the mesoblast, as are also the salivary glands. The lining of their ducts is, however, derived from the hypoblast.

The Fœtal Circulation.

Describe the fœtal circulation?

The blood in the placenta, aërated and well nourished, passes up the umbilical vein to the navel, where it enters the body of the fœtus, and, after a short course, reaches the liver, where it is split up into two streams, one of which supplies the lobes of the liver, while the other passes through the *ductus venosus*, which lies in the longitudinal fissure of the liver, into the inferior vena cava and right auricle of the heart, but instead of passing into the right ventricle it is directed by the Eustachian valve along the back of the auricle

to the foramen ovale, and immediately enters the left auricle; the left auricle, contracting, propels it into the left ventricle, which drives it into the general circulation.

What is the difference in the circulation of blood in the inferior vena cava from that of the superior vena cava?

The blood returning from the head, or superior vena cava, passes into the right auricle and enters the right ventricle (which the blood from the inferior vena cava does not). When the right ventricle contracts the blood is driven into the pulmonary artery, but instead of being distributed through the lungs it is directed through a channel given off by the left pulmonary artery, known as the ductus arteriosus, into the aorta just beyond the point where the left subclavian is given off from that vessel. The right ventricle and the left ventricle may, therefore, be said to drive the blood through the general circulation in fœtal life. As the result of this, however, it will be seen that in the aorta we have blood, half of which is aërated and half of which is not.

In what way does the blood return to the placenta to be nourished and oxygenated?

It passes through the descending aorta, the common iliacs, and the umbilical artery, by which it reaches the placenta.

What changes take place in the circulation at birth?

Respiration is commenced, the lungs become expanded, and, in consequence of this, the pulmonary vessels permit the blood to traverse them freely. The ductus arteriosus being no longer required, contracts and shrivels up, but remains as a fibrous cord. At the same time the detachment of the placenta leads to the immediate arrest of the flow of blood from the umbilical arteries, and no flow passes along the umbilical vein. The ductus venosus contracts, the currents of the superior and inferior vena cava mix in the right side of the heart, and the Eustachian valve and the foramen ovale become useless.

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